The Role of Experience in the Organization and Refinement of Face Space

by

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A thesis submitted in partial fulfillment
of the requirements for the degree
Doctor of Philosophy

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St. Catharines, Ontario

September 2014

Abstract

Adults code faces in reference to category-specific norms that represent the different face categories encountered in the environment (e.g., race, age). Reliance on such norm-based coding appears to aid recognition, but few studies have examined the development of separable prototypes and the way in which experience influences the refinement of the coding dimensions associated with different face categories. The present dissertation was thus designed to investigate the organization and refinement of face space and the role of experience in shaping sensitivity to its underlying dimensions.

In Study 1, I demonstrated that face space is organized with regard to norms that reflect face categories that are both visually and socially distinct. These results provide an indication of the types of category-specific prototypes that can conceivably exist in face space. Study 2 was designed to investigate whether children rely on category-specific prototypes and the extent to which experience facilitates the development of separable norms. I demonstrated that unlike adults and older children, 5-year-olds rely on a relatively undifferentiated face space, even for categories with which they receive ample experience. These results suggest that the dimensions of face space undergo significant refinement throughout childhood; 5 years of experience with a face category is not sufficient to facilitate the development of separable norms.

In Studies 3 through 5, I examined how early and continuous exposure to young adult faces may optimize the face processing system for the dimensions of young relative to older adult faces. In Study 3, I found evidence for a young adult bias in attentional allocation among young and older adults. However, whereas young adults showed an own-age recognition advantage, older adults exhibited comparable recognition for young and older faces. These results suggest that despite the significant experience that older adults have with older faces, the early and continuous exposure they received with young faces continues to influence their recognition, perhaps because face space is optimized for young faces.

In Studies 4 and 5, I examined whether sensitivity to deviations from the norm is superior for young relative to older adult faces. I used normality/attractiveness judgments as a measure of this sensitivity; to examine whether biases were specific to norm-based coding, I asked participants to discriminate between the same faces. Both young and older adults were more accurate when tested with young relative to older faces—but only when judging normality. Like adults, 3- and 7-year-olds were more accurate in judging the attractiveness of young faces; however, unlike adults, this bias extended to the discrimination task. Thus by 3 years of age children are more sensitive to differences among young relative to older faces, suggesting that young children’s perceptual system is more finely tuned for young than older adult faces. Collectively, the results of this dissertation help elucidate the development of category-specific norms and clarify the role of experience in shaping sensitivity to the dimensions of face space.
Keywords: norm-based coding; face space; aftereffects; face race; face age

Acknowledgements

This thesis would not have been possible without the help and support of so many people. First, I would like to thank my supervisor, Dr. Cathy Mondloch, for her guidance and expertise throughout the completion of both my Masters and PhD work. Her insight and frequent feedback greatly contributed to the success of this project and to my development as an independent researcher. I would also like to thank my committee members, Kang Lee and Karen Arnell, who provided valuable feedback throughout the completion of this project.

Second, I would like to thank the members of the Face Perception Lab—graduate students, post-docs, research assistants, and volunteers—for their daily support, friendship, and humor. In particular, I would like to thank the graduate students who have worked alongside me throughout my Masters and PhD: Danielle Longfield, Alex Hatry, Matt Horner, Thalia Semplonius, Valentina Proietti, and Xiaomei Zhou. Their friendship and support has been an invaluable gift. Lastly, I would like to thank my family, friends, and past professors at Wittenberg University, who have always had faith in me and encouraged me to achieve my dreams.

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CHAPTER 1

General Introduction

Adults are considered experts in face processing and are capable of recognizing and discriminating between hundreds of human faces. They process faces holistically rather than parsing a face into its constituent features (Carey & Diamond, 1994; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987) and exhibit exquisite sensitivity to both featural and relational (i.e., feature spacing) cues to identity (for a review, see Maurer, Le Grand, & Mondloch, 2002). Such expertise is significantly influenced by experience. For example, recognition accuracy is higher for faces presented in an upright relative to inverted orientation (Yin, 1969) and for own- relative to other-race faces (Meissner & Brigham, 2001; Rhodes, Hayward, & Winkler, 2006). This differential performance is presumably due to years of experience in discriminating between upright faces and to predominant exposure to own-race faces.

Faces are highly relevant social stimuli that are repeatedly encountered in everyday life, which may account for the near-universal expertise that adults display for this stimulus category. Faces appear to be preferentially attended to relative to non-face stimuli (e.g., Brown, Huey, & Findlay, 1997; Hershler & Hochstein, 2005; Langton, Law, Burton, & Schweinberger, 2008) and engage specialized neural resources (reviewed in Haxby & Gobbini, 2011). Three regions in the occipito-temporal visual cortex are particularly responsive to face relative to non-face stimuli: the lateral fusiform gyrus (referred to as the fusiform face area or FFA; e.g., Kanwisher, McDermott, & Chun, 1997), the occipital face area (OFA; Gauthier et al., 2000), and the posterior superior temporal sulcus (pSTS; Puce, Allison, Bentin, Gore, & McCarthy, 1998); among adults, activity in each of these regions tends to show right hemispheric dominance (reviewed in Kanwisher & Barton, 2011). Moreover, electrophysiological studies have consistently identified several ERP components associated with face processing. The N170 is a face-specific neural correlate that reflects the structural encoding of human faces (Bentin, Allison, Puce, Perez, & McCarthy, 1996), whereas the N250 is sensitive to the repetition of human faces and is associated with face recognition (Puce, Allison, & McCarthy, 1999; Schweinberger, 2011; Schweinberger, Kaufmann, Moratti, Keil, & Burton, 2007; Zheng, Mondloch, & Segalowitz, 2012). Given that selective brain regions and electrophysiological components are associated with face processing, many researchers have posited that faces represent a unique class of visual stimuli that are "special" relative to other object categories (for a review, see McKone & Robbins, 2011).

Norm-based Coding

Expertise in face processing requires fine-tuned sensitivity to the differences between faces, an ability traditionally attributed to the use of norm-based coding. According to Valentine (1991), individual faces are encoded relative to a face prototype (i.e., average face) that has been extracted from all faces previously encountered in the environment. Individual faces differ on a variety of dimensions (e.g., distance between the eyes, size of the nose), and each dimension is represented as a unique vector in a multidimensional face space. Within this face space, individual faces are represented as distinct points; the farther a face is from the prototype, the more distinctive and the less attractive it appears (Potter & Corneille, 2008; Rhodes & Tremewan, 1996; Valentine, Darling, & Donnelly, 2004).

The face prototype is dynamic and continuously updated by experience. Adaptation is an experimental method commonly employed to examine the malleability of the prototype. For example, repeated exposure to faces distorted in a similar direction (e.g., features compressed inward) produces a temporary shift in the prototype, which subsequently alters perceived attractiveness such that unaltered faces appear distorted in the opposite direction while similarly distorted faces appear more attractive (Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003; Webster & MacLin, 1999). Such figural attractiveness aftereffects provide behavioral evidence of a transient change in the norm and highlight the dynamic nature of the prototype. Aftereffects are presumed to reflect reduced neural activation following repeated stimulation (Ibbotson, 2005). Shifts in the norm are clearly evident at the neural level for figural aftereffects, as shown by reduced hemodynamic activity in the frontal and occipital cortex in response to undistorted faces following adaptation to distorted faces (Fu et al., 2014). Aftereffects have been found not only for the perception of attractiveness but also for the perception of sex, race, emotional expression, and age (Webster, Kaping, Mizokami, & Dumahel, 2004; O'Neil & Webster, 2011). For example, following exposure to a single face category (e.g., male faces), previously ambiguous faces appear to belong to the opposite category (i.e., female).

Additional support for norm-based coding comes from studies investigating the perception of identity. When participants are adapted to a face that is the computational opposite of an identity (e.g., "anti-Dan"), perception is biased such that a previously ambiguous face takes on the characteristics of the original identity (i.e., "Dan"; Anderson & Wilson, 2005; Leopold, O'Toole, Vetter, & Blanz, 2001). Aftereffects are larger when faces lie along the same identity trajectory (e.g., Dan and anti-Dan) than when faces are equally perceptually dissimilar but do not lie along the same trajectory (e.g., Dan and Jim), suggesting a special role for the norm in the coding of identity (Rhodes & Jeffery, 2006).

Face aftereffects do not simply reflect low-level retinotopic adaptation, as aftereffects persist even when the retinal size and position of the adapting and test stimuli do not match (e.g., Rhodes et al., 2003; Rhodes, Jeffery, Clifford, & Leopold, 2007). Although low-level adaptation may partially contribute to face aftereffects (Zhao & Chubb, 2001), recent research reveals that face aftereffects largely reflect adaptation of high-level face-coding mechanisms. For example, whereas aftereffects for inverted faces derive entirely from mid-level shape-generic mechanisms (e.g., curvature, convexity), upright face aftereffects are generated from both shape-generic and face-specific mechanisms (as shown by almost complete transfer of aftereffects between Ts and inverted faces and only partial transfer of aftereffects between Ts and upright faces; Susilo, McKone, & Edwards, 2010). Moreover, evidence from a recent fNIRS study (Fu et al., 2014) suggests that figural face aftereffects are mediated by activity in brain regions associated with later stages of the visual processing pathway. Following exposure to compressed faces, there was a significant reduction in [oxy-Hb] activity in response to undistorted faces in an extended network of regions in the frontal and occipital cortices, indicative of adaptation of high-level cortical mechanisms.

Norm-based coding is often contrasted with exemplar-based coding in which individual faces are encoded with regard to the absolute value of each dimension in face space (see Figure 1.1). Although both models posit the existence of a norm, in exemplar-based coding the norm holds no special significance. These two theoretical models are

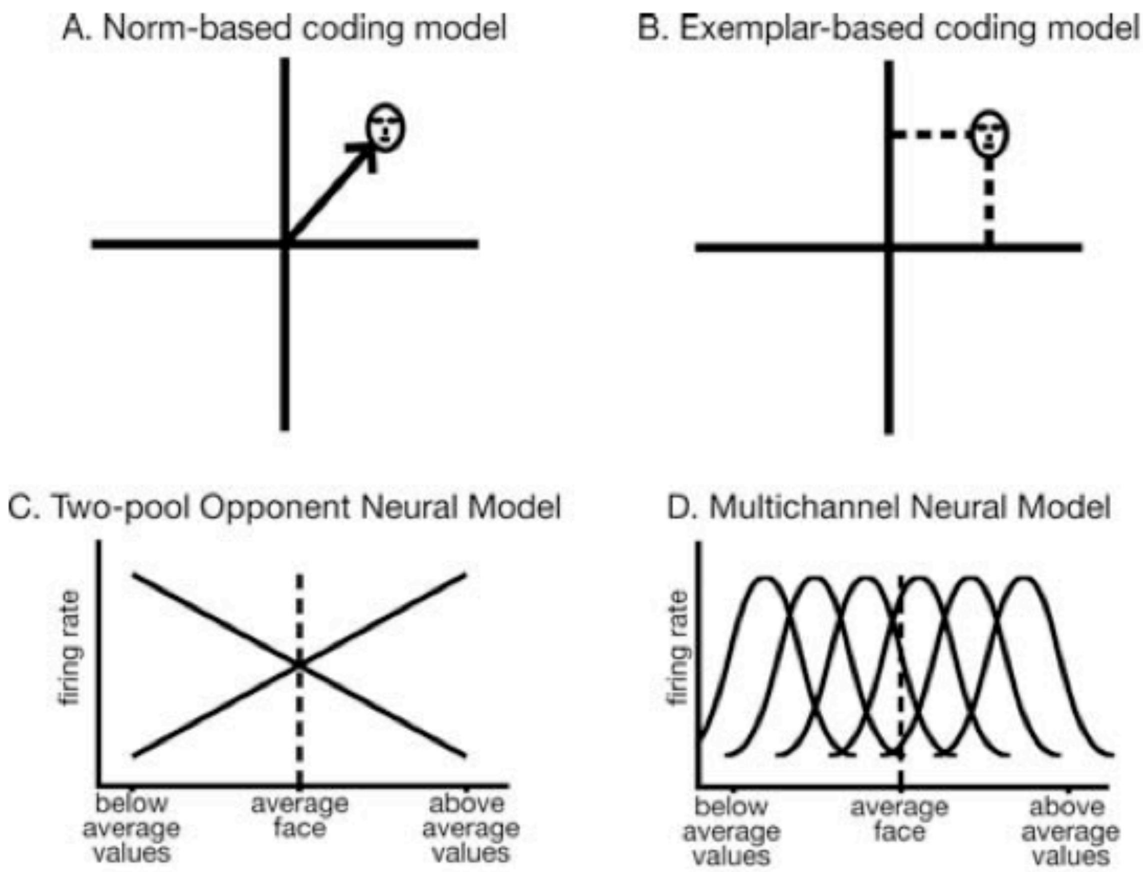

Figure 1.1. Two-dimensional theoretical models demonstrating norm-based coding (A) and exemplar-based coding (B). Row 2 represents the neural models associated with the theoretical perspectives: two-pool opponent coding (C) and multichannel coding (D). Taken from Jeffery, L., Rhodes, G., McKone, E., Pellicano, E., Crookes, K., & Taylor, E. (2011). Distinguishing norm-based from exemplar-based coding of identity in children: Evidence from face identity aftereffects. *Journal of Experimental Psychology: Human Perception and Performance, 37*(6), 1824-1840. Published by APA.

associated with neural coding models taken from low-level vision research: two-pool opponent coding (considered analogous to norm-based coding) and multichannel coding (analogous to exemplar-based coding; e.g., Leopold, Bondar, & Giese, 2006; Tsao & Freiwald, 2006). In two-pool opponent coding, oppositely tuned neural populations respond maximally to the extreme values of each dimension (e.g., distance between the eyes) in face space. The norm is thus associated with equal response or firing rates in these two neural pools. In contrast, in multichannel coding, values along a dimension are coded by multiple neural pools, with a bell-shaped tuning curve associated with each value; these tuning curves overlap with those of the neighboring values but not with values that are quite distant from each other (Jeffery et al., 2010).

Both norm-based coding and exemplar-based models can account for adaptation aftereffects; however, the two models make different predictions. First, only norm-based coding predicts that adapting to an undistorted face will produce no shift in attractiveness preferences because an undistorted face is already activating equal responsiveness in opponent pools of neurons. Second, the norm-based coding model predicts that adaptation to more extreme adaptors will produce larger aftereffects than adaptation to less extreme adaptors (see Figure 1.2). In contrast, exemplar-based coding predicts that adaptation to faces that are less extreme will produce larger aftereffects because extreme adaptors activate neural pools whose values share minimal overlap with pools coding the average values (for a review, see Jeffery et al., 2011).

There is substantial evidence that norm-based coding best describes the way in which adults code faces. First, adaptation to undistorted faces does not alter perceptions of normality (Burkhardt et al., 2010). As predicted by norm-based coding models, single-

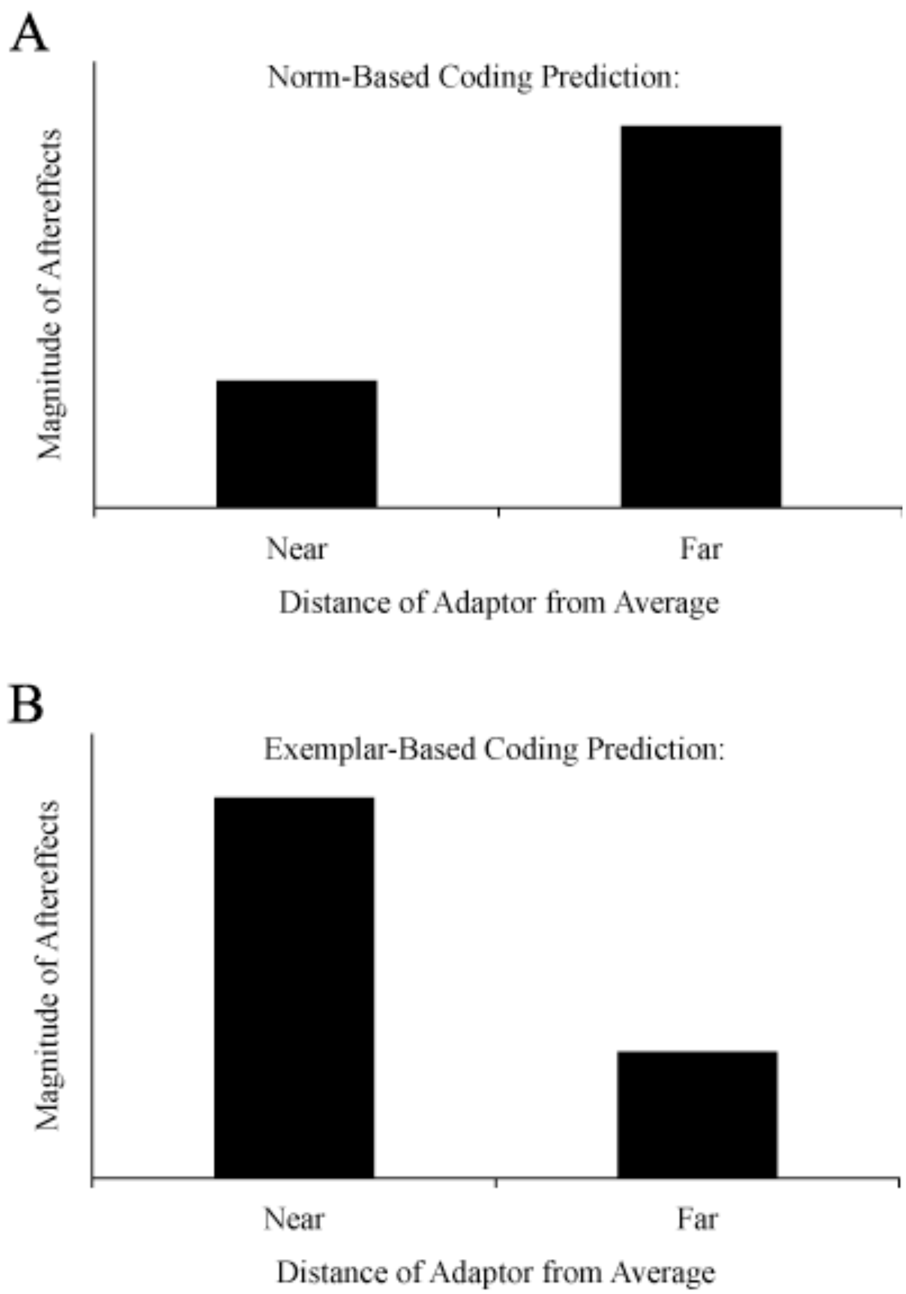

Figure 1.2. Predictions regarding the magnitude of aftereffects following adaptation to near versus far adaptors for norm-based coding (A) and exemplar-based coding (B). Adapted from Jeffery, L., Rhodes, G., McKone, E., Pellicano, E., Crookes, K., & Taylor, E. (2011). Distinguishing norm-based from exemplar-based coding of identity in children: Evidence from face identity aftereffects. *Journal of Experimental Psychology: Human Perception and Performance, 37*(6), 1824-1840. Published by APA.

cell recording studies have demonstrated that neural responses in the anterior inferotemporal cortex of macaque monkeys become stronger as distance from the average face increases (Leopold et al., 2006), and electrophysiological studies with humans have shown that the amplitude of the N250 increases as a function of identify strength (Kaufman & Schweinberger, 2008; Zheng et al., 2012). Lastly, for identity and figural adaptation, the more extreme the adaptor is, the larger the aftereffect (Rhodes et al., 2005; Robbins, McKone, & Edwards, 2007), which provides additional evidence of norm-based coding because the farther an adaptor is from the norm, the greater the activation and thus the more the norm shifts in the expected direction (see Jeffery et al., 2010).

Norm-based coding underlies the perception of face identity (Robbins et al., 2007; but see Ross, Deroche, & Palmeri, 2014), gender (Pond et al., 2013), emotional expression (Skinner & Benton, 2010), and even body identity (Rhodes, Jeffery, Boeing, & Calder, 2013) and is thought to facilitate discrimination around the norm (Wilson, Loffler, & Wilkinson, 2002). Norm-based coding appears to be particularly economical relative to exemplar-based coding because in norm-based coding, face dimensions are coded relative to pairs of neural populations rather than multiple populations of neurons, which reduces responses to typical (i.e., average) faces and may be associated with lessened metabolic costs (Rhodes & Leopold, 2011). Furthermore, norm-based coding reduces redundancy in the information shared by all faces, which frees neural resources and allows for greater sensitivity to the distinctive characteristics of individual faces, enhancing recognition (Rhodes & Leopold, 2011; Rhodes, Watson, Jeffery, & Clifford, 2010; Webster & MacLeod, 2011). Consistent with this account, among typical adult populations, there is a positive correlation between face recognition memory and the magnitude of the figural face aftereffect (Dennett, McKone, Edwards, & Susilo, 2012). Moreover, individuals with congenital prosopagnosia (Palermo, Rivolta, Wilson, & Jeffery, 2011) and autism (Ewing, Pellicano, & Rhodes, 2013; Pellicano, Jeffery, Burr, & Rhodes, 2007), both of which are associated with deficits in face processing, show reduced identity aftereffects relative to typical populations. Such findings highlight the functional role of norm-based coding in face recognition and suggest that atypical updating of the face prototype is associated with impaired face processing.

Although Valentine's (1991) model assumes that all faces are coded relative to a single face prototype, recent research has revealed that adults possess multiple face prototypes that represent the different face categories encountered in the environment (e.g., race). Evidence for category-contingent prototypes stems from studies that examine opposing aftereffects. Following exposure to face categories distorted in opposite directions (e.g., compressed Caucasian and expanded Chinese faces), adults' judgments of attractiveness/normality shift in opposite directions, which is possible only if these faces are represented with regard to separable norms and at least some category-specific coding dimensions. Reliance on separable norms may enhance recognition; identification thresholds are lower around a race-specific relative to a mixed-race/race-generic average (Armann, Jeffery, Calder, & Rhodes, 2011). Opposing aftereffects have been found for faces that differ based on race (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008), sex (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005), orientation (Rhodes et al., 2004), age, and species (Little et al., 2008). Opposing aftereffects indicate that faces from different categories are coded with regard to some category-specific dimensions; however, partial transfer of aftereffects studies reveal that there is also some overlap in the coding dimensions used for these faces (Jaquet & Rhodes, 2008). For example, when adults are adapted to distorted faces of one race, significant aftereffects emerge for a face race that was never shown during adaptation but these aftereffects are smaller than those of the adapted race (Jaquet et al., 2008). Such partial transfer of aftereffects reflects the shared coding dimensions across race categories.

Children's Face Processing

There is evidence that even young children exhibit several characteristic of adult-like face processing. Like adults, they process faces holistically (de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Le Grand, Maurer, & de Schonen, 2007; Pellicano & Rhodes, 2003) and are more accurate in recognizing upright relative to inverted faces (Macchi Cassia, Kuefner, Picozzi, & Vescovo, 2009; Mondloch, Le Grand, & Maurer, 2002) and own- relative to other-race faces (e.g., Sangrigoli & de Schonen, 2004). Furthermore, they show sensitivity to featural and relational cues to identity (e.g., Macchi Cassia, Turati, & Schwarzer, 2011; McKone & Boyer, 2006; Mondloch et al., 2002). In fact, even infants appear to process faces in a holistic manner (Ferguson, Kulkofsky, Cashon, & Casasola, 2009; Schwarzer & Zauner, 2003; Schwarzer, Zauner, & Jovanovic, 2007) and are sensitive to differences among faces in feature spacing (Hayden, Bhatt, Reed, Corbly, & Joseph, 2007; Quinn & Tanaka, 2009).

Despite this sensitivity, children continue to make more errors than adults on a variety of face perception tasks until mid-adolescence (Baudouin, Gallay, Durand, & Robichon, 2010; de Heering, Rossion, & Maurer, 2012; Freire & Lee, 2001; Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch & Thomson, 2008; Schwarzer, 2000).

Therefore although the mechanisms that underlie expert face processing are in place by early childhood, these mechanisms likely undergo considerable refinement throughout childhood. There is debate as to whether improvements in face perception during childhood reflect domain-general or face-specific development. According to the *early maturity* view, all face processing skills are both qualitatively and quantitatively in place by age 5, and any improvements in face perception are due to the increased development of general cognitive skills such as memory and attention (e.g., Crookes & McKone, 2009; McKone, Crookes, Jeffery, & Dilks, 2012). For example, Weigelt et al. (2014) report improved performance in face perception and face memory tasks between 5 and 10 years of age. However, whereas improvements in face memory were domain specific, improvements in face perception were not; similar improvements in perception were observed for the perception of cars, bodies, and scenes. Alternatively, the *late maturity* perspective argues that the mechanisms that underlie adult-like face processing are qualitatively present early in life but that significant face-specific quantitative improvement in these mechanisms occurs up until adolescence (e.g., Baudouin et al., 2010; Mondloch et al., 2004). This argument is supported by studies showing that even when memory demands are eliminated, children continue to show reduced performance on a number of face perception tasks (Freire & Lee, 2001; Mondloch et al., 2004).

Recent research has examined whether deficits in children's face processing may be attributed to an immature way of representing faces and decreased reliance on norm-based coding (reviewed in Jeffery & Rhodes, 2011). There is evidence that children as young as 4 years rely on norm-based coding. At this age, children show both figural (Jeffery et al., 2010; Short, Hatry, & Mondloch, 2011) and identity aftereffects (Jeffery, Read, & Rhodes, 2013). Like adults, larger adapters produce stronger aftereffects in children (Jeffery et al., 2013; Jeffery et al., 2011), and even expression appears to be coded in a norm-based manner by age 9 (youngest age tested; Burton, Jeffery, Skinner, Benton, & Rhodes, 2013). Although there is some evidence that children's face space might be more malleable than adults' (e.g., Hills, Holland, & Lewis, 2010), most studies have found that adults' and children's aftereffects are similar in size (Jeffery et al., 2010; Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008) and that the temporal dynamics of aftereffects are analogous in adults and children as young as 8 years (Nishimura, Robertson, & Maurer, 2011).

Children thus appear to represent faces in a multidimensional face space that has at least some adult-like characteristics. However, children may differ from adults in the organization or refinement of their face space. For example, although children exhibit evidence for norm-based coding, they require greater differences among faces in order to consistently rate unaltered faces as more attractive than faces with compressed or expanded features (Anzures, Mondloch, & Lackner, 2009; Crookes & McKone, 2009; Jeffery et al., 2010), which demonstrates that they are less sensitive to deviations from the norm. Furthermore, although 8-year-old children tend to rely on the same coding dimensions as adults, they exhibit difficulty utilizing more than one dimension at a time (Nishimura, Maurer, & Gao, 2009). It may also be the case that unlike adults, children rely on a single prototype and its corresponding dimensions even when processing faces from different categories. There is some evidence that children's face space is less differentiated with regard to orientation. Although 8-year-olds show partial transfer of aftereffects across upright and inverted faces (Jeffery, Taylor, & Rhodes, in press), 10-

year-old children show no evidence for orientation-contingent opposing aftereffects (Robbins, Maurer, Hatry, Anzures, & Mondloch, 2012), suggesting that children's separable norms for upright and inverted faces may not be as robust as though of adults.

There is also evidence that children as young as 8 years possess race-specific norms. Using an opposing aftereffects paradigm, Short et al. (2011) found that Caucasian 8-year-olds rely on separable prototypes for Caucasian and Chinese faces; aftereffects were driven by significant shifts in attractiveness preferences for both face races. However, when Caucasian 5-year-olds were tested with a similar paradigm, they showed opposing aftereffects that were driven almost entirely by simple aftereffects for own-race faces. These results suggest that 5-year-olds' face space may be less well refined than that of adults' and 8-year-olds'.

Short and colleagues (2011) proposed two models that could underlie the organization of young children's face space (see Figure 1.3). First, it could be that Caucasian 5-year-olds possess both a Caucasian and a Chinese prototype; however, the Chinese prototype is weakly defined relative to the Caucasian prototype. In this model, there is a great deal of overlap between the coding dimensions used for Caucasian faces and the coding dimensions used for Chinese faces, perhaps due to a lack of experience with other-race faces. Alternatively, it could be the case that Caucasian 5-year-olds possess a highly specified Caucasian prototype but have not yet formed a Chinese prototype due to a lack of exposure to other-race faces. Thus, whereas Caucasian faces are encoded relative to a face norm, Chinese faces are encoded at an individual, exemplar-based level. Regardless of which model best describes young children's face space, the results of Short et al. (2011) suggest that 5-year-olds rely on a face space that

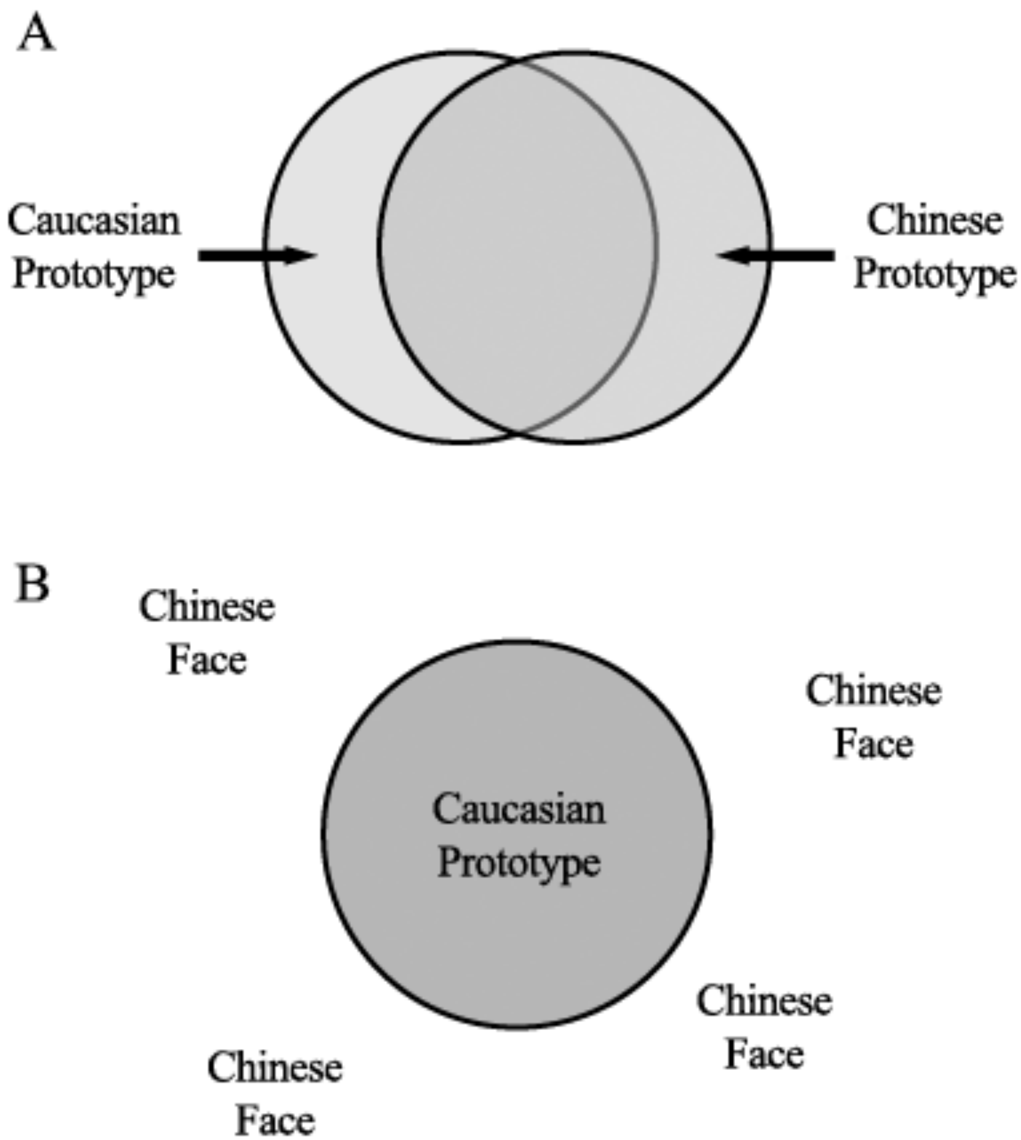

Figure 1.3. Two models outlining the potential organization of Caucasian 5-year-olds' face space with regard to race. Model A assumes that Caucasian 5-year-olds possess race-specific but highly overlapping prototypes for Caucasian and Chinese faces. In contrast, Model B assumes that Caucasian faces are coded in reference to a prototype but that Chinese faces are encoded as individual exemplars.

is less well refined and more poorly differentiated with regard to face race relative to adults and older children.

Role of Experience

Both adults' and children's expertise in face processing is considerably influenced by experience. For example, recognition is best for upright human faces of our own race (Pascalis & Bachevalier, 1998; Rhodes et al., 2006). Such biases in recognition are thought to be due to differential perceptual expertise for faces from different categories. According to perceptual expertise accounts, reduced experience with other face categories (e.g., other-race faces) leads to their being processed less holistically (Michel, Caldara, & Rossion, 2006; Tanaka, Kiefer, & Bukach, 2004) and to reduced sensitivity to differences among faces in the shape and spacing of facial features (Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010). This viewpoint contrasts with those of socio-cognitive theorists, who argue that different social cognitions are elicited by in- (e.g., own-race) and out-group (e.g., other-race) individuals (Sporer, 2001). Unlike in-group members, members of an out-group are processed at the categorical level (Hugenberg, Young, Bernstein, & Sacco, 2010), which leads to reduced encoding of their individuating features (Ge et al., 2009; Levin, 2000).

Experience appears to exert an influence on face processing skills from very early in life. The vast majority of developmental research investigating the role of experience has examined the effect of predominant exposure to own-race faces on infants' and children's recognition for own- and other-race faces (reviewed in Anzures, Quinn, Pascalis, Slater, & Lee, 2013a). At birth, infants possess a broad face processing system that begins to narrow as a function of experience. Newborn infants show no visual preference for own- or other-race faces; however, by 3 months of age, they preferentially attend to faces of their own race (Kelly et al., 2005). Likewise, the ability to discriminate individual identities for other-race faces progressively narrows throughout the first year of life (reviewed in Anzures et al., 2013b). Whereas 3-month-olds can discriminate faces regardless of face race, by 9 months infants are capable of discriminating between only own-race faces (Kelly et al., 2007). Moreover, 4-month-olds process both own- and other-race faces holistically, but by 8 months of age, infants exhibit this ability only for own-race faces (Ferguson et al., 2009). Children as young as 3 years show a consistent own-race recognition advantage (Sangrigoli & de Schonen, 2004), and continued exposure to predominantly own-race faces maintains the magnitude of this effect between 5 and 10 years of age (Anzures et al., 2014). However, this effect can be reversed if children receive ample exposure to other-race faces before age 9 (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005). Such results demonstrate that the face processing system remains plastic throughout childhood and is amenable to changes in the face environment to which children are exposed.

Another category by which faces vary is age, yet much less is known about the role of experience in shaping recognition for own- versus other-age faces. Age is an inherently more difficult face category to examine relative to race. Whereas face race is a stable characteristic, age, and hence the age of faces to which one is exposed, changes across the lifespan. This complexity may underlie some of the discrepant findings in the literature. Some researchers (e.g., Macchi Cassia, 2011) argue that young adult faces are the most frequently encountered face age category early in life (Rennels & Davis, 2008) and this early and continuous exposure sets up a life-long perceptual bias for young adult faces with later experience having less impact. For example, a recent study (Macchi Cassia, Bulf, Quadrelli, & Proietti, 2014) reported that the perceptual system appears to narrow for young adult relative to infant faces during the first year of life; whereas 3-month-old infants show above-chance discrimination abilities for both infant and young adult faces, 9-month-olds exhibit reliable discrimination only for young adult faces. These results suggest that similar to the process observed for face race (e.g., Kelly et al., 2007), predominant exposure to young adult faces early in life may specialize the face processing system for young adult faces. Consistent with this argument, several studies have reported that young adults show a consistent own-age recognition advantage (Rhodes & Anastasi, 2012) and that children and older adults show comparable recognition for young adult and own-age faces (e.g., Fulton & Bartlett, 1991; Wallis, Lipp, & Vanman, 2012; Wiese, Schweinberger, & Hansen, 2008; Wolff, Wiese, & Schweinberger, 2012).

Additional evidence for the role of early experience is evident in a series of studies demonstrating the impact of early-life exposure to younger/older siblings. Macchi Cassia et al. (2009) recently reported that mothers of infants show better recognition for upright relative to inverted young adult faces but no such inversion effect for infant faces (i.e., a marker for the other-age effect) only if they did not have a younger sibling as a child. In contrast, mothers of infants who had a younger sibling as a child show an inversion effect for both young adult and infant faces. Similarly, 3-year-old children with older siblings (i.e., those who received experience with child faces during infancy) exhibit comparable recognition for child and young adult faces whereas children without older siblings demonstrate better recognition for young adult than child faces (Macchi

Cassia, Pisacane, & Gava, 2012); such effects are specific to own-race faces, indicating that the effects of early experience with a given face age do not transfer to less frequently encountered face categories (Macchi Cassia, Luo, Pisacane, Li, & Lee, 2014). The results of these studies suggest that early-acquired experience with infant and child faces is sufficient to exert an effect on recognition abilities later in life.

In contrast, other researchers have argued that more recent life experience exerts significant influence on recognition abilities. For example, some studies have reported better recognition for own- relative to other-age faces across all participant age groups (e.g., Anastasi & Rhodes, 2005; Perfect & Harris, 2003; Rhodes & Anastasi, 2012) and have found that experience later in life can weaken or completely eliminate face age biases. Young adults working as preschool teachers are equally accurate in recognizing young adult and child faces (Harrison & Hole, 2009; Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008) and maternity ward nurses exhibit a smaller recognition advantage for young adult relative to infant faces than young adults who lack experience with infants (Macchi Cassia, Picozzi, Kuefner, & Casati, 2009; but see Yovel et al., 2012). Similarly, unlike young adults who have minimal experience with older adults, young adults who work in nursing homes demonstrate comparable discrimination accuracy for young and older adult faces (Proietti, Pisacane, & Macchi Cassia, 2013). There is some evidence that older adults show an own-age recognition advantage; however, this advantage emerges only when participants indicate considerable daily contact with other older adults (Wiese, Komes, & Schweinberger, 2012). Examining older adults' recognition abilities for faces of different ages is a particularly promising avenue for research because older adults have received considerable exposure to all face ages across the lifespan. Thus it is possible to examine the cumulative effects of experience with different face ages throughout life as well as the specific effects of recent exposure to and social identification with older adults.

In summary, adults' expertise in face processing is at least partially attributable to the use of norm-based coding. Although the basic mechanisms that underlie this expertise are in place by infancy and early childhood, considerable refinement of these mechanisms likely occurs throughout childhood. Experience clearly plays a role in the development of the face processing system; recognition is enhanced for own-race faces and for either own-age or young adult faces. Past research has largely taken an either/or perspective on maturation, focusing on whether improvements in face processing reflect domain-general or face-specific development. However, childhood may best be described as a period of refinement, and few studies have specifically examined how refinement of the underlying dimensions of face space contributes to expertise in face processing. The present series of studies was designed to investigate the organization and refinement of face space, emphasizing two face categories: race (children) and age (children and older adults).

The Current Research

The current research was designed to examine the role of experience in shaping the organization and refinement of face space with regard to two salient face categories—race and age. Given that I relied on a norm-based coding framework throughout the current body of research, I first examined the conditions necessary to elicit opposing aftereffects in adults. In particular, I investigated whether social categorical differences in the absence of physical differences are sufficient to elicit opposing aftereffects. Although past research has demonstrated that physical differences alone do not elicit opposing aftereffects (Bestelmeyer et al., 2008; Jaquet, Rhodes, & Hayward, 2007), it is important to establish that this also holds true for social categories; if social differences alone are capable of eliciting opposing aftereffects, this would indicate that such aftereffects might not reflect sensitivity to the actual coding dimensions of face space but instead reflect sensitivity to only high-level semantic category membership. I then investigated the role of experience in refining the dimensions of face space by examining 1) the emergence of separable prototypes for face race, and 2) sensitivity to deviations from normality in young and older faces. By examining groups of participants with varying degrees of experience with different face categories on a series of face perception tasks (e.g., adaptation, recognition, normality judgments), I aimed to provide a description of the way in which experience sets up and potentially modifies the organization of face space and its associated coding dimensions.

In Study 1, I briefly examined the conditions under which category-contingent opposing aftereffects occur in adults. Past research has repeatedly demonstrated that adults show opposing aftereffects for visually distinct categories such as race, sex, and age (Jaquet & Rhodes, 2008; Jaquet et al., 2008; Little et al., 2005; Little, et al., 2008). However, no study to date has investigated whether a category-specific physical difference is necessary for the emergence of opposing aftereffects. In this study, I manipulated the social categorical differences between faces while holding the physical differences constant and examined whether opposing aftereffects emerge for faces differing in personality type. I found that although adults showed better recognition for own- than other-personality faces, they showed no evidence for category-contingent opposing aftereffects. These results demonstrate the limits of opposing aftereffects and provide an indication of the types of category-specific prototypes that can conceivably exist in adults' face space.

Study 2 was designed to follow up the results of Short et al. (2011) and to further examine the extent to which refinements in norm-based coding may contribute to children's tendency to make more errors than adults on face perception tasks. In particular, I investigated whether 5-year-olds rely on category-specific norms and whether experience facilitates the development of dissociable face prototypes. I first examined whether Chinese 5-year-olds show race-contingent opposing aftereffects and the extent to which aftereffects transfer across face race among Caucasian and Chinese 5-year-olds. Unlike the stimuli used in Study 1, the face categories used in Study 2 (i.e., Caucasian and Chinese faces) differed both in physiognomic structure (Farkas, 1988) and in social categorical membership. Both participant races showed partial transfer of aftereffects across face race; however, there was no evidence for race-contingent opposing aftereffects. To examine whether experience facilitates the development of category-specific prototypes, I investigated whether race-contingent aftereffects are present among Caucasian 5-year-olds with abundant exposure to Chinese faces (i.e., children living in a multiethnic metropolitan region) and then tested separate groups of 5-year-olds with two other categories with which they have considerable experience: face sex and age. Across all three categories, 5-year-olds showed no category-contingent opposing aftereffects. These results demonstrate that 5 years of age is a stage characterized by minimal separation in the norms and associated coding dimensions used for faces from different categories and suggest that refinement of the mechanisms that underlie expert face processing occurs throughout childhood.

In Studies 3 through 5, I examined the way in which early and cumulative life experience with young adult faces may bias the face processing system toward the dimensions of young adult faces. The own-age recognition advantage is a less robust phenomenon than the own-race recognition advantage, and most studies investigating this effect have relied on methods that lack ecological validity. Thus I began by first investigating young and older adults' recognition memory for young and older faces presented in the context of scenes that mimic how faces are encountered in the real world. As part of this study, I also examined participants' attentional allocation during learning and whether differential attentional allocation influences subsequent recognition. In Study 3, young and older adults' eye movements were recorded as they viewed a series of scenes containing young and older faces. Participants then completed an old/new recognition task. Both young and older adults looked longer at young than older faces; however, young adults showed an own-age recognition advantage whereas older adults showed comparable recognition for the two face ages. Furthermore, attentional allocation during learning did not influence the magnitude of the own-age recognition advantage. These results provide evidence for a young adult face bias in attentional allocation but suggest that longer looking does not necessarily indicate deeper encoding. Given that older adults showed comparable recognition for young and older faces, these results also suggest that cumulative life experience with young faces continues to exert influence later in life and may prevent a loss in recognition accuracy for young faces even when those faces are not seen as regularly in older adulthood.

It may be the case that continued recognition for young faces later in life is supported by reliance on a face space that is optimized for the dimensions of young adult faces. Thus, in the final series of studies, I examined whether sensitivity to deviations from the norm is enhanced for young relative to older adult faces. In Study 4, young and older adults were shown young and older face pairs in which one member of each pair was undistorted and the other had compressed or expanded features. Participants indicated which member of each pair was more normal and which was more expanded. Both age groups were more accurate when tested with young compared to older faces—but only when judging normality, and this advantage disappeared when faces were inverted. These results suggest that the dimensions of face space are optimized for young adult faces and that abundant experience with older faces later in life does not reverse this perceptual tuning. In Study 5, I examined whether abundant experience with young adult faces leads to a bias for young faces among even young children. I tested 3- and 7-year-old children on a child-friendly version of the task used in Study 4. Similar to young adults and senior citizens, both 3- and 7-year-olds were more sensitive to detecting deviations from normality in young than older faces. However, unlike young and older adults, children's young adult face bias extended to a discrimination task. These results suggest that by 3 years of age, children's perceptual system is more finely tuned for young than older adult faces, which may support past findings of superior recognition for young adult faces.

Collectively, the results of the five studies in this dissertation help us to better understand the organization of face space and the role of experience in shaping sensitivity to its underlying dimensions. Face space is organized with regard to norms that reflect face categories that are both visually and socially distinct; a social difference alone is not sufficient to elicit opposing aftereffects. Moreover, the results of these studies demonstrate that the dimensions of face space become increasingly refined throughout childhood and suggest that early experience with young adult faces may lead to a processing advantage for young adult faces, which may support continued recognition for young adult faces even later in life. However, early biases do not necessarily require reliance on separable norms. Five-year-old children show no evidence for category-specific face prototypes; however, children as young as 3 years show a general bias in estimating attractiveness and discriminating young adult faces. As the face processing system becomes increasingly refined and specialized throughout childhood, this bias may become specific to the use of norm-based coding and reflect decreased sensitivity to the dimensions of categories less frequently experienced.

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CHAPTER 2

Study 1: The Importance of Social Factors Is A Matter of Perception[1]

Human faces provide salient information about group membership that influences subsequent processing. For example, own-race faces are processed at the individual level whereas other-race faces are processed at the categorical level; consequently, other-race faces ‘pop out’ from an array of own-race faces, are categorized faster (Levin, 1996; 2000) and recognized less accurately than own-race faces (Meissner & Brigham, 2001). These effects have traditionally been attributed to perceptual expertise (i.e., to adults’ lack of experience with other-race faces). However, the other-race effect has recently been mimicked in a surprising series of studies in which faces were randomly assigned to two social categories with no systematic physical differences. For example, Caucasian adults recognize own-personality faces better than other-personality faces, despite all faces being Caucasian males (Bernstein, Young, & Hugenberg, 2007). Similar effects have been observed for faces differing in university affiliation and socioeconomic status (Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008), leading Hugenburg and colleagues to claim “sovereignty” for social-cognitive models of the other-race effect with only limited “explanatory power of perceptual expertise theories” (Shriver et al., 2008, p. 272). We challenge their assertions by demonstrating that social-cognitive models cannot account for a different phenomenon reflecting differential processing of own- versus other-race faces: category-contingent opposing attractiveness aftereffects.

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[1] This chapter is based on the published article: Short, L. A., & Mondloch, C. J. (2010). The importance of social factors is a matter of perception. *Perception, 39*, 1562-1564. doi: 10.1068/p6758. The article was published in the Short and Sweet section of the journal, which requires that the topic appeals to a broad audience and is written in a more relaxed formatting style (i.e., no separate Method and Results sections).

Adults' expertise in face processing has been attributed to norm-based coding, a process by which individual faces are coded in reference to a face prototype (Valentine, 1991). Faces near the prototype are rated as more attractive and typical than faces that are distant. Simple attractiveness aftereffects indicate that adults' face prototype is continuously updated by experience; viewing distorted faces for a few minutes shifts the prototype toward those faces, making them appear more normal and attractive (Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003). Adults possess multiple face prototypes that correspond to the different face categories encountered in the environment. Distorting two face categories in opposite directions shifts the two prototypes and attractiveness/normality preferences in opposite directions. Opposing aftereffects have been reported for race, sex, orientation, age, and species and suggest that separable neural populations code for faces from different categories (Jaquet, Rhodes, & Hayward, 2008; Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005, Little, DeBruine, Jones, & Waitt, 2008; Rhodes et al., 2004). Two recent studies demonstrate that distinct social categories are necessary; opposing aftereffects are mitigated or absent when faces differ physically but belong to the same social category (e.g., Chinese/super-Chinese[2]) (Bestelmeyer et al., 2008; Jaquet, Rhodes, & Hayward, 2007).

To investigate whether social categories are sufficient (i.e., whether physical differences are even necessary) we randomly assigned 30 Caucasian undergraduates (23 female; *M* = 21.57 years, age range = 19-27) to one of two personality types (Crimson versus Cyan) after they received false feedback on a personality inventory (see Appendix 2); during testing participants wore a matching colored wristband. On pre- and post-

[2] Super-Chinese faces were made by caricaturing Chinese faces so as to exaggerate any race-specifying characteristics.

adaptation trials, participants viewed 16 face pairs consisting of an expanded (+10%) and a compressed version (-10%) of a Caucasian female face. Each face pair consisted of two faces of the same identity that were distorted in opposite directions. For half of the pairs, both faces were presented on a crimson background and for the other half of the pairs, both faces were presented on a cyan background (see Figure 2.1). Participants were told that the background color indicated whether the target face had the same personality (i.e., was an in-group member) or the opposite personality (i.e., was an out-group member). Participants selected the most normal looking face in each pair. During adaptation, participants viewed 20 new faces; faces on one background (n = 10 per background) were expanded (+60%) and faces on the other background were compressed (-60%). Each face was randomly presented six times for 3 seconds. Opposing aftereffects would be evident if the number of expanded faces chosen as more normal increased more for the personality type that was expanded during adaptation than for the personality type that was compressed. No differences were expected pre-adaptation. Following post-adaptation trials, participants completed an old/new recognition task in which the 20 adaptation faces were presented among 20 novel faces. Half of the novel faces were presented on a crimson background and half were presented on a cyan background; distortions matched those seen during adaptation. The 20 previously shown faces were displayed on the same background on which they had been presented during adaptation.

We replicated the in-group recognition advantage shown by Hugenberg and colleagues. Adults recognized in-group faces (d' = 1.97, SE = .19) more accurately than out-group faces (d' = 1.64, SE = .17), $t(29)$ = 2.11, p = .04, two-tailed. To determine whether participants showed opposing aftereffects, we calculated the proportion of trials on which participants selected the expanded face as most normal for each personality type pre- and post-adaptation. We then calculated change scores by subtracting the proportion of expanded faces selected as most normal pre-adaptation from the proportion of expanded faces selected as most normal post-adaptation for both the expanded personality type and the compressed personality type. For each adaptation condition (expanded/compressed), half of the judgments were from crimson faces and half were from cyan faces, because half of participants were adapted to compressed crimson faces and the other half were adapted to compressed cyan faces.

Because change scores may be influenced by pre-adaptation judgments, we first examined whether the proportion of expanded faces selected as most normal pre-adaptation differed for the personality type to be expanded versus the personality type to be compressed. A paired-samples t-test revealed that prior to adaptation the proportion of trials in which the expanded face was selected as most normal did not differ between the personality to be expanded ($M = .47$, $SE = .04$) and the personality to be compressed ($M = .50$, $SE = .04$), $t(29) = .74$, $p = .47$, two-tailed.

To determine whether participants showed opposing aftereffects, we examined whether the change in the proportion of expanded faces selected as most normal differed between the personality type that was expanded and the personality type that was compressed. The proportion of expanded faces selected as most normal did not increase any more for the personality type that was expanded ($M = -.02$, $SE = .05$) than for the personality type that was compressed ($M = -.06$, $SE = .04$), $t(29) = -.62$, $p = .54$, two-tailed, which indicates that social categories alone were not sufficient to elicit opposing aftereffects.

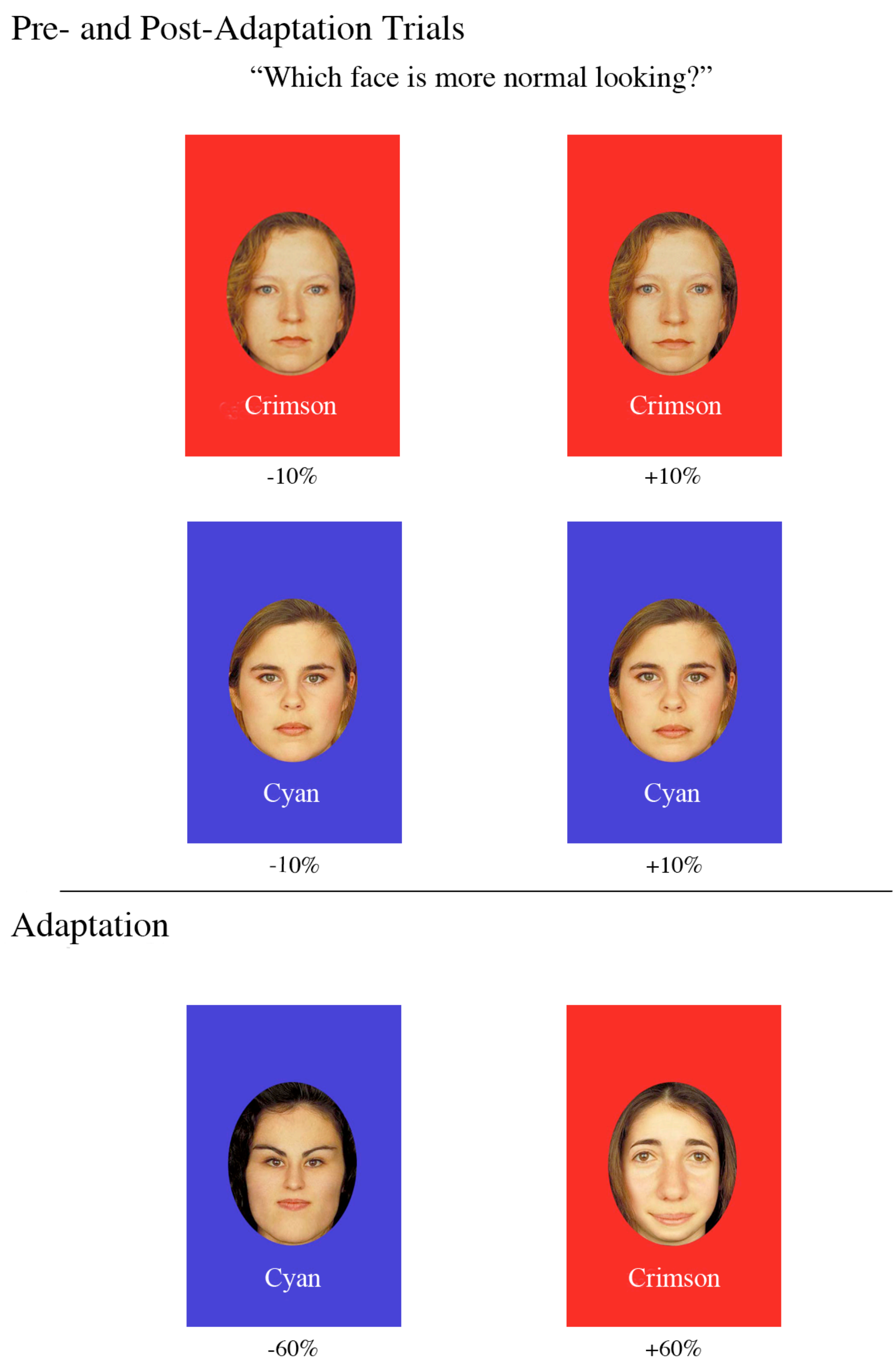

Figure 2.1. Samples of stimuli shown during pre- and post-adaptation trials and adaptation.

To further confirm that participants showed no evidence of even simple aftereffects for in-group faces, we examined whether participants who were adapted to the personality that was compressed showed significant simple aftereffects for the compressed personality faces and whether participants who were adapted to the personality that was expanded showed significant simple aftereffects for the expanded personality faces. Single-sample t-tests comparing change scores to 0 showed no evidence of simple aftereffects for in-group faces in both participant groups, ps $> .33$. Such results suggest that exposure to oppositely distorted faces simply cancelled out any simple aftereffects in the context of an opposing aftereffects paradigm with faces that differed only in social categorical membership.

The current research limits the explanatory power of social-cognitive models of the other-race effect: Social categorization in the absence of systematic physical differences cannot account for category-contingent opposing aftereffects. Such results lend support to the perceptual expertise model of face processing. Social categorization may contribute to a range of phenomena frequently associated with the other-race effect but does not provide the whole story. In sum, both social-cognitive and perceptual models provide incomplete insights about how we process faces that belong to different categories. Not surprisingly, a complete understanding of how we perceive the human face—an inherently social stimulus with which adults have abundant experience—requires integration of these two theoretical approaches.

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CHAPTER 3

Study 2: The Development of Category-Specific Face Prototypes[3]

Young children demonstrate several characteristics of adult-like face processing. They process faces holistically (e.g., de Heering, Houthuys, & Rossion, 2007), are more accurate in recognizing upright versus inverted faces (e.g., Mondloch, Le Grand, & Maurer, 2002) and own- versus other-race faces (e.g., Sangrigoli & de Schonen, 2004), and show sensitivity to featural and relational (i.e., feature spacing) cues to identity (e.g., McKone & Boyer, 2006; Mondloch et al., 2002). Despite these abilities, they continue to make more errors on a variety of face perception tasks until mid-adolescence (e.g., Baudouin, Gallay, Durand, & Robichon, 2010; de Heering, Rossion, & Maurer, 2012; Freire & Lee, 2001; Mondloch, Dobson, Parsons, & Maurer, 2004; Schwarzer, 2000). There is debate as to whether these age-related improvements in face processing can be attributed to face-specific perceptual development or to more general cognitive and perceptual development (reviewed in McKone, Crookes, Jeffery, & Dilks, 2012). For example, Weigelt et al. (2014) report improved performance in both face perception and face memory tasks between 5 and 10 years of age. However, whereas improvements in face memory were domain specific, improvements in face perception were not; similar improvements in perception were observed for cars, bodies, and scenes.

Regardless of the extent to which improvements in face perception during childhood reflect domain-specific versus domain-general development, two statements appear to be accurate: 1) Many of the mechanisms underlying adult-like face processing are present early in life (McKone et al., 2012); and 2) Face perception (e.g., the ability to

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[3]This chapter is based on the published article: Short, L. A., Lee, K., Fu, G., & Mondloch, C. J. (2014). Category-specific prototypes are emerging, but not yet mature in 5-year-old children. *Journal of Experimental Child Psychology, 126,* 161-177. doi: 10.1016/j.jecp.2014.04.004

discriminate faces) continues to improve throughout childhood (e.g., Baudouin et al., 2010; Mondloch et al., 2004). Thus, childhood may be characterized as a period of refinement. For example, although even infants are sensitive to differences among faces in feature spacing (Hayden, Bhatt, Reed, Corbly, & Joseph, 2007), adult-like sensitivity develops after 10 years of age (Mondloch et al., 2002), even when memory demands are eliminated (Mondloch et al., 2004). In the present study, we examined the extent to which refinements in norm-based face coding may contribute to children's tendency to make more errors than adults on face perception tasks. In particular, we examined whether 5-year-olds' face space is less well refined than that of adults with regard to the dimensions of faces from different categories.

Norm-based Coding

Adult expertise in face processing has traditionally been attributed to the use of norm-based coding. According to Valentine (1991), individual faces are encoded relative to a face prototype (i.e., average face) extracted from all faces previously encountered. Individual faces differ on a variety of dimensions (e.g., distance between the eyes), and each dimension is represented as a unique vector in a multidimensional face space. Within this face space, individual faces are represented as distinct points; the farther a face is from the prototype, the more distinctive and the less attractive it appears (Rhodes & Tremewan, 1996).

The face prototype is continuously updated by experience. Adaptation is an experimental method commonly employed to examine the malleability of the prototype. For example, repeated exposure to faces distorted in a similar direction (e.g., features compressed inward) produces a temporary shift in the prototype, which results in unaltered faces appearing distorted in the opposite direction while similarly distorted faces appear more attractive (referred to as figural aftereffects; Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003; Webster & MacLin, 1999). Judgments of attractiveness thus require participants to reference a norm that is temporarily altered by exposure to distorted faces. Aftereffects have been found for the perception of sex, race, emotional expression (Webster, Kaping, Mizokami, & Dumahel, 2004), age (O'Neil & Webster, 2011), and identity (e.g., Anderson & Wilson, 2005; Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006). Furthermore, for both identity and figural adaptation, the more extreme the adaptor is, the larger the aftereffect (Rhodes et al., 2005; Robbins, McKone, & Edwards, 2007), which provides additional evidence of norm-based coding (Jeffery et al., 2010).

In adults, norm-based coding underlies the perception of face identity (Robbins et al., 2007; but see Ross, Deroche, & Palmeri, 2014) and is thought to facilitate discrimination around the norm (Wilson, Loffler, & Wilkinson, 2002) by reducing redundancy in the information shared by all faces, which frees neural resources and allows for greater sensitivity to the distinctive characteristics of individual faces (Rhodes & Leopold, 2011; Rhodes, Watson, Jeffery, & Clifford, 2010; Webster & MacLeod, 2011). Consistent with this account, there is a positive correlation between face recognition memory and the magnitude of aftereffects (Dennett, McKone, Edwards, & Susilo, 2012; Rhodes, Jeffery, Taylor, Hayward, & Ewing, 2014). Moreover, individuals with congenital prosopagnosia (Palermo, Rivolta, Wilson, & Jeffery, 2011) and autism (e.g., Ewing, Pellicano, & Rhodes, 2013), both of which are associated with deficits in face processing, show reduced identity aftereffects relative to typical populations.

Children as young as 4 years rely on norm-based coding (reviewed in Jeffery & Rhodes, 2011). At this age, children show both figural (Jeffery et al., 2010; Short, Hatry, & Mondloch, 2011) and identity aftereffects (Jeffery, Read, & Rhodes, 2013). Like adults, more extreme adapters produce stronger aftereffects in children (Jeffery et al., 2013; Jeffery et al., 2011), and even expression appears to be coded in a norm-based manner by 9 years of age (youngest age tested; Burton, Jeffery, Skinner, Benton, & Rhodes, 2013). Although there is some evidence that children's face space might be more malleable than adults' (e.g., Hills, Holland, & Lewis, 2010), most studies have found that adults' and children's aftereffects are similar in size (Jeffery et al., 2010; Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008) and that the temporal dynamics of aftereffects are analogous in adults and children as young as 8 years (Nishimura, Robertson, & Maurer, 2011).

Refinement of Face Space

Children appear to represent faces in a multidimensional face space that has at least some adult-like characteristics. However, children may differ from adults in the organization or refinement of their face space. For example, although children exhibit evidence for norm-based coding, they require greater differences among faces in order to consistently rate unaltered faces as more attractive than faces with compressed or expanded features (Anzures, Mondloch, & Lackner, 2009; Crookes & McKone, 2009; Jeffery et al., 2010), which demonstrates that they are less sensitive to deviations from the norm. Furthermore, although 8-year-old children tend to rely on the same coding dimensions as adults, they exhibit difficulty utilizing more than one dimension at a time (Nishimura, Maurer, & Gao, 2009).

In the current study, we tested another factor that may contribute to the slow development of expert face processing: a reliance on a face space that is relatively undifferentiated with regard to faces from different categories. Adults possess multiple face prototypes that represent the different face categories encountered in the environment (e.g., race). Such separable prototypes may aid recognition; identification thresholds are lower around a race-specific relative to a mixed-race/race-generic average (Armann, Jeffery, Calder, & Rhodes, 2011). Following adaptation to two face categories distorted in opposite directions (e.g., compressed Caucasian and expanded Chinese faces), adults' judgments of attractiveness/normality shift in opposite directions, which is possible only if these faces are represented with regard to separable norms and at least some category-specific coding dimensions (see Farkas, 1988 for physiognomic differences). Such opposing aftereffects have been found for faces that differ according to race (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008), sex (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005), orientation (Rhodes et al., 2004), age, and species (Little et al., 2008). Although opposing aftereffects indicate that faces from different categories are coded with regard to some category-specific dimensions, there is also some overlap in the coding dimensions used for these faces (Jaquet & Rhodes, 2008). When adults are adapted to distorted faces of one race, significant aftereffects emerge for a face race that was never shown during adaptation but these aftereffects are smaller than those of the adapted race (Jaquet et al., 2008). Such partial transfer of aftereffects reflects the shared coding dimensions across categories.

It may be the case that unlike adults, children rely on a single prototype and its corresponding dimensions for all faces. Using an opposing aftereffects paradigm, Short et al. (2011) found evidence for race-specific norms (Caucasian/Chinese) in Caucasian 8-year-old children and some evidence for dissociable norms in Caucasian 5-year-olds; however, opposing aftereffects in 5-year-olds were driven almost entirely by simple aftereffects for own-race faces, which suggests that 5-year-olds' face space may be less well refined than that of adults and 8-year-olds. It is therefore possible that 5 years of age is a stage characterized by the emergence of separable norms for own- and other-race faces.

The Current Study

The current study was designed to further examine whether 5-year-old children rely on race-specific norms and investigate whether experience facilitates the development of dissociable face prototypes. In all studies, we used the storybook method initially designed by Anzures et al. (2009) to examine figural attractiveness aftereffects. In Experiment 1, we examined whether, like Caucasian 5-year-olds with minimal experience with other-race faces (Short et al., 2011), Chinese 5-year-olds show race-contingent aftereffects driven by simple aftereffects for own-race faces. We then used a transfer of aftereffects study in which Caucasian and Chinese children were adapted to distorted faces from a single race and tested with faces of both races. The goal of this second study was to determine if 5-year-olds show simple aftereffects for other-race faces and the extent to which aftereffects transfer across races.

In Experiment 1, all participants had minimal experience with faces from the opponent category (i.e., other-race faces). In Experiments 2 and 3, we examined whether ample experience with a given category facilitates the development of category-specific prototypes in 5-year-old children. We investigated whether race-contingent aftereffects are present among Caucasian 5-year-olds who have ample exposure to Chinese faces and then tested children with two other categories with which they have considerable experience: sex (male/female faces) and age (adult/child faces).

Experiment 1a: Race-Contingent Aftereffects Among Chinese 5-Year-Olds

Race is a highly meaningful face category for young children and is therefore suitable for examining category-specific face norms. Infants show own-race biases in visual preference and face recognition tasks (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005; Kelly et al., 2007). Moreover, children as young as 3 years show a consistent own-race recognition advantage (Sangrigoli & de Schonen, 2004), and by 4 years display social biases based on race (Bigler & Liben, 1993) and attend to race when making inferences about the social relationships between children (Shutts, Roben, & Spelke, 2013).

In Short et al. (2011), Caucasian 5-year-olds showed race-contingent aftereffects; however, these effects were driven by simple aftereffects for own-race faces with no shifts in attractiveness preferences for other-race faces. Crucially, all children tested in this study were from a predominantly Caucasian community and had minimal experience with Chinese faces. This weak evidence for opposing aftereffects suggests that young children who have minimal experience with other-race faces may not represent own- and other-race faces with regard to dissociable norms. To examine the robustness of this finding, we used the same method employed by Short et al. to test whether Chinese 5-year-olds who have minimal experience with Caucasian faces show race-contingent aftereffects.

Method

Participants. We tested 24 Chinese 5-year-olds (±6 months of age; 12 female) from Jinhua, China, a city with a population that is 99.99% Chinese. An additional 3 children were tested but excluded from all analyses because they failed to meet criterion (n = 2) or were inattentive during testing (n = 1).

Materials. The original computerized storybook used by Short et al. (2011) was translated into Mandarin for Chinese participants. Stimuli consisted of colored photographs of Caucasian and mainland Chinese 4- to 6-year-old children. Faces were distorted using the spherize function in Adobe Photoshop Version 8.0. The experiment consisted of three phases: pre-adaptation attractiveness trials, adaptation, and post-adaptation attractiveness trials (See Figure 3.1). Pre- and post-adaptation stimuli were divided into two sets of 16 face pairs (eight per race); each pair consisted of two versions of the same identity. In each set, there were four face pairs for each race comprising an unaltered face paired with an expanded face (+70%) and four face pairs comprising an unaltered face paired with a compressed face (-70%). Face pairs from one set were shown pre-adaptation and face pairs from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants. Faces of 12 different identities (six Caucasian, six Chinese) were used as adaptation stimuli and were presented in the context of the 5-minute computerized storybook used by Short et al. In the storybook, Caucasian faces were distorted in one direction while Chinese faces were distorted in the opposite direction (±90%). Only one face race was presented on each page and race of face alternated from page to page.

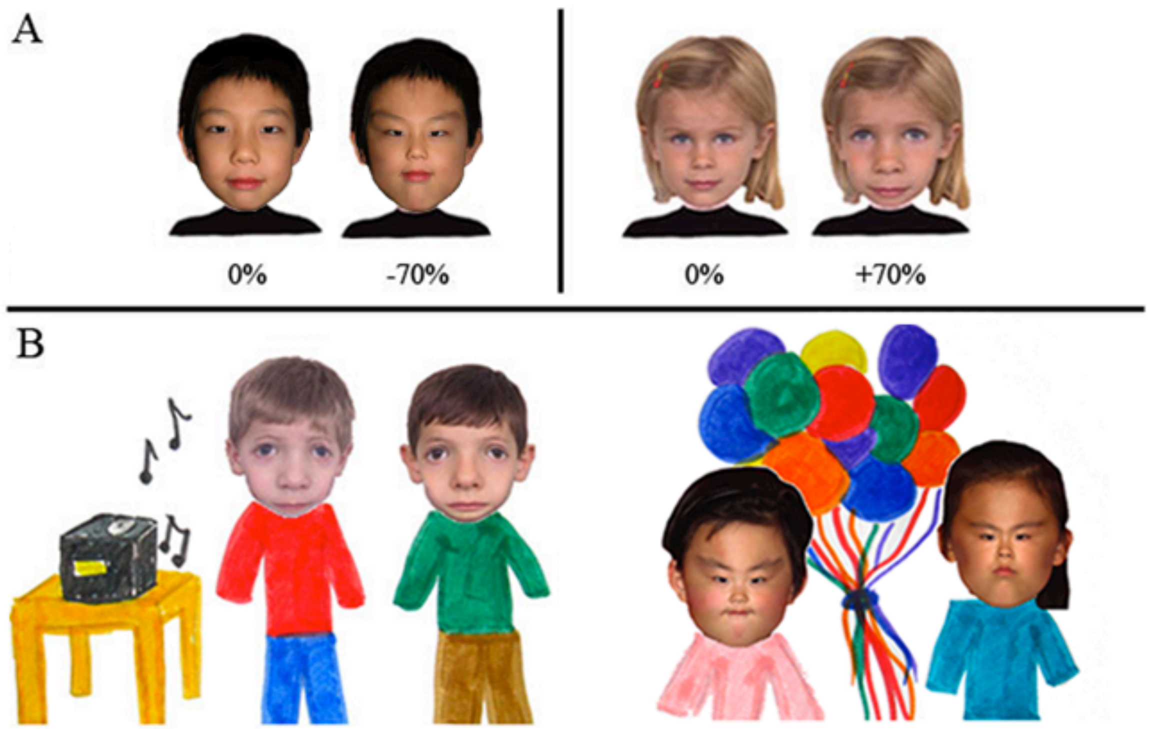

Figure 3.1. Sample face pairs shown during test trials in Experiments 1 and 2 (A). Sample pages from the adaptation storybook used in Experiment 1a (B). In Experiment 1b, children were adapted to only one face race, and in all other experiments children were adapted to faces from two categories distorted in opposite directions.

Procedure. The testing procedure was identical to that described in Short et al. (2011, Experiment 4). Children were seated in front of a 24-inch computer monitor and completed two sets of criterion trials to ensure that they understood task instructions. In each set of trials, children were simultaneously shown three objects that varied in attractiveness. They were then shown two objects at a time (n = 2 trials) and pointed to the prettiest object in each pair. Children were excluded from all analyses if they made more than one error, defined as selecting a less attractive item (e.g., a paper bag) as more attractive than the more attractive item with which it was paired (e.g., a green present with polka dots).

Children then completed 16 pre-adaptation trials. Children were told that they would be shown pairs of siblings and that their job was to point to the prettiest or most handsome face in each pair. Each child viewed 16 pairs (eight Caucasian, eight Chinese). Each face pair remained on the screen for 3 seconds and was then replaced with a blank screen. Participants indicated their choice by pointing to the side of the screen on which the prettier face appeared. The next trial did not begin until a response had been made.

After pre-adaptation trials were completed, participants were read a 5-minute story about two birthday parties, one attended by Caucasian children and the other by Chinese children. Half of the participants were adapted to expanded Caucasian faces (+90%) and compressed Chinese faces (-90%) and the other half were adapted to compressed Caucasian faces and expanded Chinese faces. Each page of the storybook contained between one and six faces, and the size and location of the faces varied to eliminate low-level retinotopic adaptation. Following the storybook, participants were shown an additional 16 face pairs (eight Caucasian) and selected the most attractive face in each pair. To maintain adaptation, face pairs remained on the screen for 3 seconds and were then replaced with a blank screen. After each post-adaptation trial two top-up faces were presented, one Caucasian and one Chinese; top-up faces were distorted in a way consistent with adaptation (Rhodes et al., 2003). The first top-up face matched the race of the previous trial and the second top-up face matched the race of the upcoming trial. Top-up faces were paired with a comment designed to encourage participants (e.g., "I agree!"), and participants received reinforcement regardless of their response.

Results and Discussion

For each participant, we recorded the number of distorted faces selected on expanded and compressed trials for the face race that was compressed during adaptation (Caucasian for half of the participants; Chinese for the other half) and for the face race that was expanded during adaptation. To determine if there were any attractiveness biases prior to adaptation, we examined whether the number of +70% and -70% faces selected as most attractive pre-adaptation differed for the race of face to be expanded and the race of face to be compressed. A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated-measures ANOVA revealed no main effects, *p*s > .31, η_p^2s ≤ .04, or interaction, $p = .35$, $\eta_p^2 = .04$, indicating that prior to adaptation children were no more likely to select the +70% or -70% face for either the race of face to be expanded or the race of face to be compressed. As expected, the number of distorted faces selected pre-adaptation was low across all conditions (*M*s ≤ 1.29).

To determine whether Chinese 5-year-olds exhibited evidence for race-contingent aftereffects, we calculated change scores for both the expanded face race and the compressed face race by subtracting the number of distorted faces selected pre-adaptation from the number of distorted faces selected post-adaptation for each level of distortion. Opposing aftereffects would be evident if following adaptation, the number of -70% faces selected as most attractive increased more for the face race that was compressed during adaptation than for the face race that was expanded, and at the same time, the number of +70% faces selected as most attractive increased more for the face race that was expanded during adaptation than for the face race that was compressed.

We conducted a 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated-measures ANOVA with the change in the number of distorted faces chosen as the dependent variable. There were no main effects, *p*s > .37, η_p^2s < .04, or interaction, $p = .22$, $\eta_p^2 = .07$. As shown in Figure 3.2a, the number of +70% faces selected as most attractive did not increase any more for the face race that was expanded during adaptation ($M = .25$, $SE = .26$) than for the face race that was compressed ($M = -.17$, $SE = .30$). Likewise, the number of -70% faces selected as most attractive did not increase any more for the face race that was compressed during adaptation ($M = .21$, $SE = .25$) than for the face race that was expanded ($M = .17$, $SE = .17$). Indeed, single-sample t-tests[4] revealed that in all conditions, the magnitude of aftereffects did not significantly differ from 0, *p*s > .32.

[4] All reported single-sample t-tests were two-tailed and uncorrected for multiple comparisons.

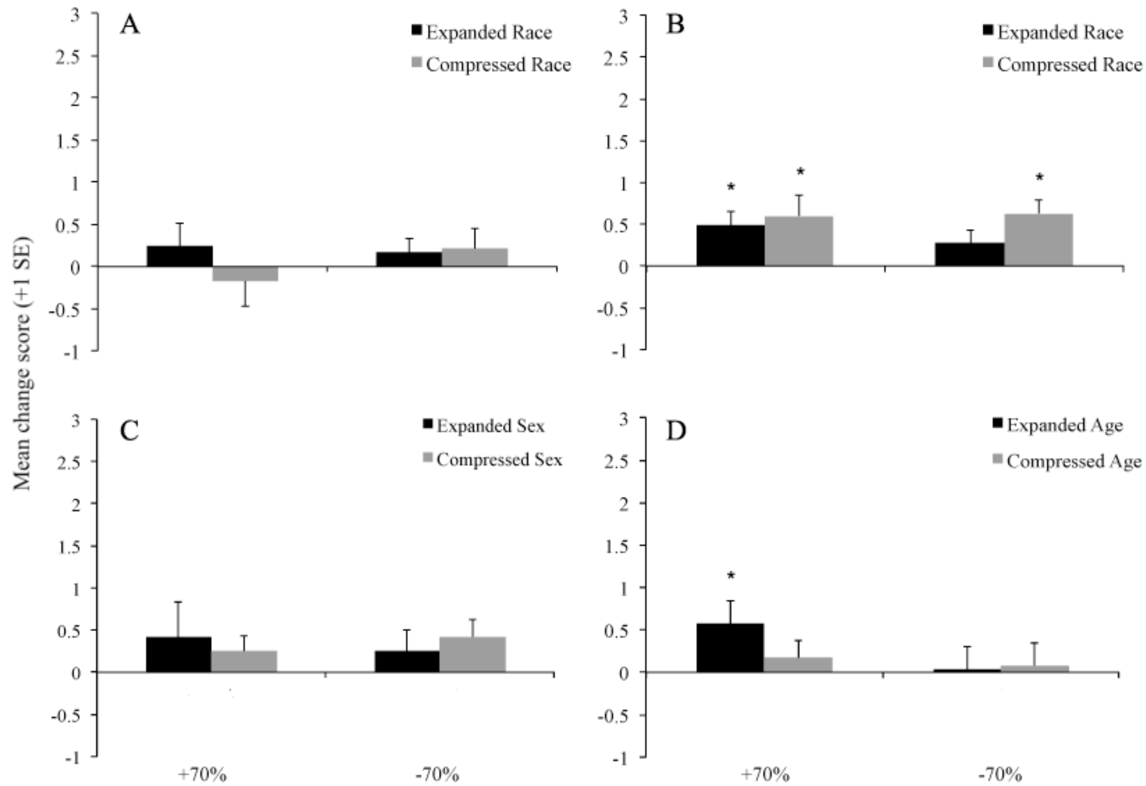

Figure 3.2. Mean change scores for +70% and -70% test faces for the face category that was expanded versus the face category that was compressed during adaptation for Experiment 1a (A. Chinese 5-year-olds tested with Chinese and Caucasian faces), Experiment 2 (B. Caucasian 5-year-olds with multicultural exposure tested with Chinese and Caucasian faces), Experiment 3a (C. 5-year-olds tested with male and female faces), and Experiment 3b (D. 5-year-olds tested with adult and child faces). Asterisks indicate that aftereffects were significantly different from 0 ($p < .05$).

Our results show no evidence for race-contingent aftereffects among Chinese 5-year-olds. However, among Caucasian 5-year-olds tested in a racially homogeneous population (Short et al., 2011), opposing aftereffects were present, though driven by simple aftereffects for own-race faces. To determine if Chinese children showed simple aftereffects for own-race faces, we conducted single-sample t-tests comparing change scores for +70% Chinese faces for the 12 children adapted to expanded Chinese faces (M = .08, SE = .45) and change scores for -70% Chinese faces for the 12 children adapted to compressed Chinese faces (M = .58, SE = .38) to 0. In both conditions, the magnitude of aftereffects did not significantly differ from 0, ps > .15.

Chinese children with minimal experience with Caucasian faces showed no evidence for separable prototypes for Caucasian and Chinese faces. Following adaptation to Caucasian and Chinese faces distorted in opposite directions, attractiveness judgments for the expanded face race did not shift in the opposite direction of attractiveness judgments for the compressed face race. These results contrast with those of Short et al. (2011); in their study, Caucasian 5-year-olds did show evidence of opposing aftereffects. However, whereas 8-year-olds' opposing aftereffects were driven by shifts in attractiveness judgments for both Caucasian and Chinese faces, 5-year-olds' opposing aftereffects were driven by shifts in attractiveness judgments only for own-race faces. Based on these findings, Short et al. concluded that separable representations for own- and other-race faces are emerging by 5 years of age.

Opposing aftereffects provide evidence that faces from different categories are represented with regard to separable norms and category-specific coding dimensions (Jaquet & Rhodes, 2008). Weak opposing aftereffects or the absence thereof suggest that the coding dimensions that 5-year-olds rely on are largely overlapping for own- and other-race faces. To directly test this hypothesis, in Experiment 1b we examined the extent to which aftereffects transfer across face race among Caucasian and Chinese 5-year-olds.

Experiment 1b: Transfer of Aftereffects Across Face Race

Participants were adapted to distorted faces of only one race but judged the attractiveness of both Caucasian and Chinese faces during pre- and post-adaptation trials. Adults show partial transfer of aftereffects across face race, indicating that there are some shared coding dimensions for own- and other-race faces (Jaquet et al., 2008). In children, complete transfer of aftereffects across face race (i.e., no difference in the magnitude of aftereffects for the face race that was adapted versus the face race that was not) would provide evidence of completely overlapping representations and coding dimensions for own- and other-race faces. Partial transfer of aftereffects would indicate separable representations with some shared underlying dimensions.

Half of the participants were adapted to distorted own-race faces and half were adapted to distorted other-race faces, which also allowed us to compare the magnitude of simple aftereffects for own- versus other-race faces. Children were adapted to compressed faces only because past studies have found that viewing compressed faces during adaptation tends to produce larger aftereffects than viewing expanded faces (Jaquet & Rhodes, 2008; Jaquet et al., 2008), and we wanted to give children every opportunity to show partial transfer of aftereffects. We previously reported figural aftereffects for own-race faces in 5-year-old children using a similar paradigm (Short et al., 2011; see also Jeffery et al., 2010). However, to date there is no evidence that adaptation shifts attractiveness judgments for other-race faces in young children. An absence of simple aftereffects for other-race faces in participants adapted to only other-race faces would suggest that these faces might be represented as individual exemplars rather than in a norm-based fashion.

Method

Participants. We tested two groups of 5-year-old children (±6 months) who had minimal contact with other-race faces: 48 Caucasian children (27 female) from St. Catharines, Ontario, who had minimal experience with Chinese faces, and 48 Chinese children (24 female) from Jinhua, China, who had minimal experience with Caucasian faces. An additional 11 children were tested but excluded from all analyses because they failed to meet criterion (n = 1), were inattentive (n = 1), or were unable to follow task instructions (n = 9).

Materials and procedure. Pre- and post-adaptation trials were similar to those used in Experiment 1a. However, adaptation stimuli were presented in the context of the computerized storybook used by Anzures et al. (2009) in which there was a single surprise birthday party that was attended by only one race of children. All of the faces in the storybook were Caucasian for half of the children and Chinese for the other half. Adapting faces were compressed by -90%. Each storybook contained eight face identities, and the identities of the adapting faces differed from those used during pre- and post-adaptation trials. A single top-up face was presented following each post-adaptation trial.

Results and Discussion

We examined whether the number of -70% faces selected as most attractive pre-adaptation differed for the race of face that matched adaptation and for the race of face that did not match adaptation across the two adaptation conditions (adapt to own-race faces, adapt to other-race faces). A 2 (face race: race that matched adapting stimuli, race that did not match adapting stimuli) x 2 (adaptation condition: adapt to own-race faces, adapt to other-race faces) mixed ANOVA for pre-adaptation trials revealed no main effects or interactions, *p*s > .14, η_p^2s ≤ .02. The number of distorted faces selected pre-adaptation was low across all conditions (*M*s ≤ .83).

To determine the magnitude of simple aftereffects, we calculated change scores for both the race of face that matched adaptation and the race of face that did not match adaptation by subtracting the number of compressed faces selected pre-adaptation from the number of compressed faces selected post-adaptation. Single-sample t-tests indicated that the magnitude of aftereffects was significantly greater than 0 in all conditions for both participant races, all *p*s < .04. We then conducted a 2 (face race: race that matched adapting stimuli, race that did not match adapting stimuli) x 2 (adaptation condition: adapt to own-race faces, adapt to other-race faces) x 2 (participant race: Caucasian, Chinese) mixed ANOVA with the change in the number of compressed faces chosen as the dependent variable. As shown in Figure 3.3, there was a main effect of face race, $F(1, 92) = 5.01$, $p = .03$, $\eta_p^2 = .05$; aftereffects were larger for the face race that matched adaptation ($M = 1.27$, $SE = .14$) than for the face race that did not match adaptation ($M = .92$, $SE = .13$), indicating partial transfer of aftereffects. There was also a main effect of participant race, $F(1, 92) = 4.92$, $p = .03$, $\eta_p^2 = .05$. The increase in the number of

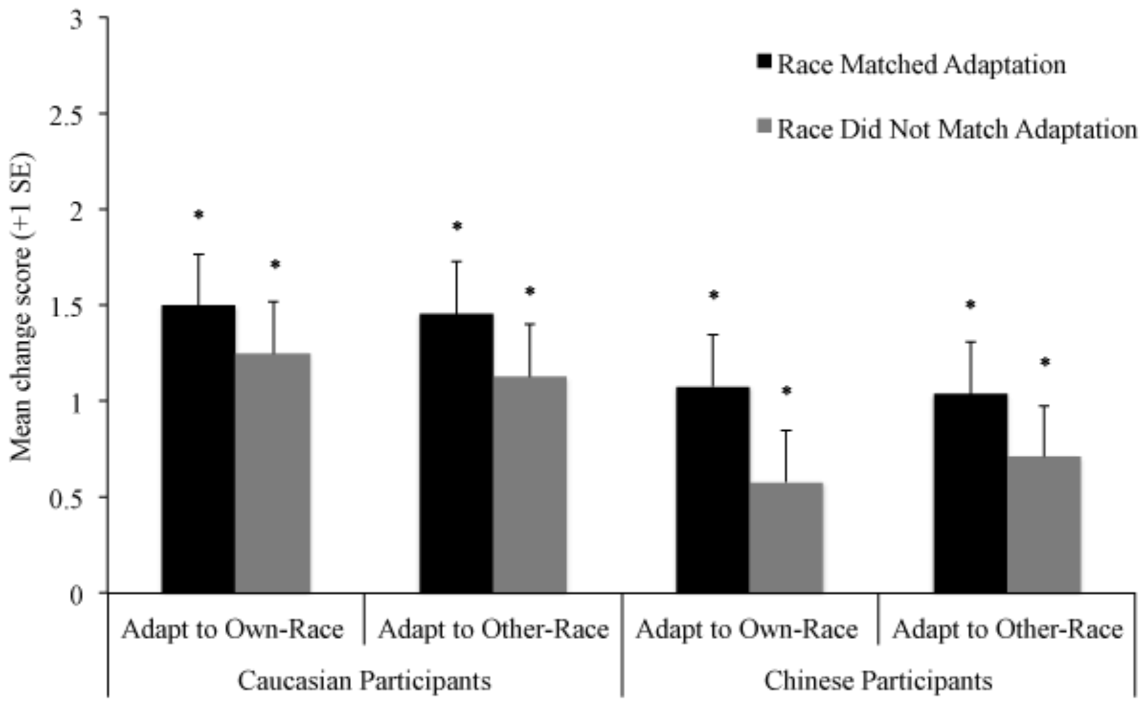

Figure 3.3. Increases in the number of -70% faces chosen following adaptation to own- versus other-race faces. Asterisks indicate that aftereffects were significantly greater than 0 ($p < .05$).

compressed faces chosen following adaptation was larger among Caucasian participants ($M = 1.33$, $SE = .15$) than Chinese participants ($M = .85$, $SE = .15$). There were no other main effects or interactions, all ps > .69, η_p^2s ≤ .002. Most notably, the magnitude of aftereffects did not differ as function of adaptation condition; aftereffects were no larger when participants adapted to own- relative to other-race faces.

There are two key findings from the present experiment. First, the magnitude of aftereffects did not differ for own- versus other-race faces, suggesting that children process other-race faces using norm-based coding. These results are consistent with the finding that expertise does not affect the magnitude of aftereffects; in adults, aftereffects are no larger for own- than other-race faces (Jaquet et al., 2008). Second, aftereffects were larger for the face race that matched adaptation relative to the face race that did not match adaptation, which indicates partial transfer of aftereffects and suggests that 5-year-olds have somewhat separable representations for own- and other-race faces. However, this dissociability may not be as great as adults' and 8-year-olds' for two reasons. First, 5-year-olds require greater distortions than adults during both adaptation and test trials in order to show these effects. Second, unlike adults and 8-year-olds, 5-year-olds show weak to no evidence for race-contingent opposing aftereffects; it may be that the opposite distortions simply cancel each other out in the context of an opposing aftereffects paradigm. Evidence that partial transfer of aftereffects emerges prior to opposing aftereffects for face race is consistent with 8-year-olds showing partial transfer of aftereffects between upright and inverted faces (Jeffery, Taylor, & Rhodes, in press) whereas 10-year-olds do not show orientation-contingent opposing aftereffects (Robbins, Maurer, Hatry, Anzures, & Mondloch, 2012).

Experiment 2: Race-Contingent Aftereffects among Children with Ample Experience with Other-Race Faces

The results of Experiment 1 indicate that separable norms and associated coding dimensions begin to emerge as early as 5 years but become increasingly refined as a function of age (see also Short et al., 2011). To the extent that experience with different face categories plays a role in the development of separable norms, it is possible that children with ample exposure to other-race faces show greater separability than children who lack this experience. In Experiment 2, we tested Caucasian 5-year-olds raised in a multiethnic community (i.e., with considerable experience with Chinese faces) with the opposing aftereffects paradigm used in Experiment 1a. We tested half of the participants with the original version of the storybook and half with a version in which the social differences between races were emphasized. Both physical and social categorical differences are necessary to elicit opposing aftereffects (Bestelmeyer et al., 2008; Jaquet, Rhodes, & Hayward, 2007; Short & Mondloch, 2010). In the race-emphasized version of the storybook, we heightened awareness of the social differences by describing the dissimilarities between the Caucasian children at the party in Canada and the Chinese children at the party in China. This condition thus provides the strongest test for race-contingent aftereffects (i.e., high experience with other-race faces; social differences emphasized).

Method

Participants. Forty-eight Caucasian 5-year-olds (±6 months of age, 24 female) participated in this study. All children were tested in Toronto, Ontario, a multicultural city with a large Chinese population. Given this large Chinese population, all children presumably encountered numerous Chinese individuals in their daily lives; in the current sample of children, 79% of parents indicated that their child attended a school or daycare where he or she regularly interacted with Chinese peers[5] (see Appendix 3 for questionnaire). An additional 6 children were tested but excluded from all analyses because they were inattentive (n = 2) or unable to follow task instructions (n = 4).

Materials and procedure. Pre- and post-adaptation test stimuli were identical to those used in Experiment 1a for all children. Half of participants were tested with the version of the storybook used in Experiment 1a. Half were tested with a different version in which the social categorical differences between the races were emphasized by describing two birthday parties that took place in different parts of the world. Children watched Matt's birthday party that took place in Canada and represented a typical North American party (e.g., children played musical chairs and ate cake) and Liyang's birthday party that took place in China and represented a traditional Chinese celebration (e.g., children hung lanterns and ate dumplings). In both versions of the storybook, one race of face was presented on each page, race of face alternated from page to page, and Caucasian and Chinese faces were distorted in opposite directions (±90%).

Results and Discussion

Analyses were identical to Experiment 1a except that the between-subjects factor of storybook version was added. A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) x 2 (storybook: original, race-emphasized) mixed ANOVA for pre-adaptation trials revealed no main effects or interactions, ps > .07, η_p^2s < .07. As

[5] We analyzed the data once with all 48 participants included and once with only the participants whose parents indicated that their child attended a daycare in which they regularly interacted with Chinese peers (n = 38). Results did not differ across conditions and thus we report analyses conducted with all 48 participants.

expected, the number of distorted faces selected pre-adaptation was low across all conditions (*M*s $\leq$ 1.08).

To determine whether 5-year-olds exhibited evidence for race-contingent aftereffects and whether storybook condition influenced the magnitude of these effects, we conducted a 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) x 2 (storybook: original, race-emphasized) mixed ANOVA with the change in the number of distorted faces chosen as the dependent variable. There was no evidence of opposing aftereffects. The adaptation condition by distortion interaction did not approach significance, $p = .51$, $\eta_p^2 = .01$, nor did the three-way interaction between adaptation condition, distortion, and storybook, $p = .59$, $\eta_p^2 = .01$. The significant interaction between adaptation condition and storybook, $F(1, 46) = 6.15$, $p = .02$, $\eta_p^2 = .12$, only reflects a greater increase in the number of both +70% and -70% faces selected among children who read the race-emphasized storybook than among those who read the original storybook. Indeed, adaptation seemed to create a non-specific tolerance for facial distortions. Single-sample t-tests revealed that for the original storybook, the magnitude of aftereffects significantly differed from 0 in all conditions, *p*s < .01, except for -70% faces for the face race that was compressed, $p = .07$. For the race-emphasized storybook, the magnitude of aftereffects significantly differed from 0 for ±70% faces for the face race that was compressed, *p*s < .02, but not for ±70% faces for the face race that was expanded, *p*s > .43. However, as shown in Figure 3.2b, for both storybook conditions, the number of +70% faces selected as most attractive did not increase any more for the expanded face race than for the compressed face race. Likewise, the number of -70%

faces selected as most attractive did not increase any more for the compressed face race than for the expanded face race.

Combined with the results of Short et al. (2011), our findings in Experiment 1 suggest that 5 years of age truly is a stage characterized by the emergence of separable representations for own- and other-race faces. The results of Experiment 2 suggest that experience does not facilitate the development of race-specific norms. Children with ample experience with other-race faces showed no evidence for race-contingent aftereffects, even when the social differences between races were emphasized. To examine whether the lack of opposing aftereffects in young children is specific to face race or extends to other relevant face categories, in Experiment 3 we investigated whether 5-year-olds show opposing aftereffects for two other categories with which children have abundant experience—sex and age of face.

Experiment 3a: Sex-Contingent Aftereffects

Sex is a highly salient and meaningful category for young children. By 3 months of age, infants show a visual preference for the face sex of their primary caregiver (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002) and by 10 months, they readily categorize faces by sex (Younger & Fearing, 1999). Between 2 and 5 years, children spontaneously classify others based on sex (reviewed in Katz & Kofkin, 1997) and show a clear preference for interacting with same-sex peers (Maccoby, 2002). The early emergence of such biases may be attributable to parents' frequent mentioning of sex differences in everyday conversations with their children (Katz & Kofkin, 1997), which heightens awareness of the distinction between males and females. Given the social relevance of face sex and the ample experience that children have with male and female faces, it is possible that the mental representation of face sex may be particularly well-refined and differentiated among even very young children.

To determine whether young children reference separable norms for face sex, we examined whether 5-year-olds show opposing aftereffects for male and female faces. If children fail to show opposing aftereffects for sex of face, this would provide additional evidence that ample experience with a face category is not sufficient to facilitate the development of category-specific norms during early childhood.

Method

Participants. Twenty-four Caucasian 5-year-olds (±6 months of age, 12 female) participated in this experiment. An additional 2 children were tested but excluded from all analyses because they were inattentive during testing (n = 1) or failed to understand task instructions (n = 1).

Materials and procedure. Stimuli consisted of colored photographs of Caucasian male and female adult faces. Female face stimuli were acquired from the Maurer Vision Lab at McMaster University and male face stimuli were acquired from the NimStim database (Tottenham et al., 2009). All faces displayed a neutral expression. All phases of the procedure were identical to Experiment 1a except that the Caucasian identities were replaced by male faces and the Chinese identities were replaced by female faces.

Results and Discussion

Analyses were identical to those of Experiment 1a. The 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated-measures ANOVA with the number of +70% and -70% faces selected as attractive during pre-adaptation trials as the dependent variable revealed no main effects or interaction, *p*s > .31, η_p^2s $\leq$ .04, indicating that children were no more likely to select the +70% or -70% face for either the face sex to be expanded or the face sex to be compressed. The number of distorted faces selected pre-adaptation was low across all conditions (*M*s $\leq .50$).

To determine whether 5-year-olds exhibited evidence for sex-contingent aftereffects, we conducted a 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated-measures ANOVA with the change in the number of distorted faces chosen as the dependent variable. There were no main effects or interaction, *p*s > .30, η_p^2s < .05 (see Figure 3.2c). Single-sample t-tests revealed that in all conditions, the magnitude of aftereffects did not significantly differ from 0, *p*s > .10, although the magnitude of aftereffects for -70% faces for the compressed face sex did approach significance, $p = .06$.

The results of Experiment 3a are consistent with our findings from Experiment 2 and suggest that 5-year-olds do not rely on separable norms even for face categories with which they have a great deal of experience. Unlike adults (Jaquet & Rhodes, 2008; Little et al., 2005), young children exhibited no evidence for sex-contingent aftereffects. To confirm our findings, in Experiment 3b we examined one other category with which children have abundant experience—face age.

Experiment 3b: Age-Contingent Aftereffects

Young adult faces are the most frequently encountered age category during infancy (Rennels & Davis, 2008); however, as children grow older and enter daycare and preschool, they receive ample experience with child faces. Information about age is rapidly extracted from faces by both adults and children (Rhodes, 2009), and even young children show differential discrimination and recognition performance for faces from different age categories (e.g., George, Hole, & Scaife, 2000; Rhodes & Anastasi, 2012). Here we examined whether young children reference separable norms for adult versus child faces.

Method

Participants. Twenty-four Caucasian 5-year-olds (±6 months of age, 12 female) participated in this experiment. An additional 4 children were tested but excluded from all analyses because they were inattentive during testing (n = 2) or stopped responding during the post-adaptation trials (n = 2).

Materials and procedure. Stimuli consisted of colored photographs of Caucasian adults and 4- to 6-year-old children. For each face age, half of the faces were female and half were male. Adult female face stimuli were acquired from the Maurer Vision Lab at McMaster University and adult male face stimuli were acquired from the NimStim database (Tottenham et al., 2009). All children's faces were obtained from a sample of photographs taken in the Face Perception Lab at Brock University. Pre- and post-adaptation trials were identical to Experiment 1a except that the Caucasian identities were replaced by adult faces and the Chinese identities were replaced by child faces.

Faces of twelve different identities (six child, six adult) were used as adaptation stimuli. These faces were presented in the context of a 5-minute computerized storybook about two parties; one party was for children only and the other was an office party for adults. Storybook pages that included child faces were hand-drawn (similar to those in Experiments 1 and 2); however, storybook pages that included adult faces were photographs taken in an office. We used different methods for presenting the adult and child faces because we wanted to ensure that children perceived the adult faces as belonging to actual adults; placing the adult faces on hand-drawn bodies made the faces appear childlike and unrepresentative of a workplace environment. Half of the participants were adapted to expanded adult faces (+90%) and compressed child faces (-90%) and the other half were adapted to the reverse condition.

Results and Discussion

All analyses were identical to those of Experiment 1a. The 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated-measures ANOVA with the number of +70% and -70% faces selected as attractive during pre-adaptation trials as the dependent variable revealed no main effects or interaction, *p*s > .15, η_p^2s < .09. Children were no more likely to select the +70% or -70% face for either the face age to be expanded or the face age to be compressed. The number of distorted faces selected pre-adaptation was low across all conditions (*M*s ≤ 1.17).

A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated-measures ANOVA with the change in the number of distorted faces chosen as the dependent variable revealed no main effects or two-way interaction, *p*s > .23, η_p^2s ≤ .06 (see Figure 3.2d). Single-sample t-tests revealed that the magnitude of aftereffects significantly differed from 0 for +70% faces for the face age that was expanded, $p = .03$. However, in all other conditions the magnitude of aftereffects did not significantly differ from 0, *p*s > .41.

Similar to face sex, we did not find evidence for age-contingent aftereffects in young children. Such converging evidence demonstrates that 5-year-olds do not rely on separable norms even for face categories with which they have a great deal of experience. Combined with the results of Experiments 1 and 2, these results suggest that 5 years of age is a stage characterized by minimal separation in the norms and associated coding dimensions used for faces from different categories.

Combined Analysis of Original Storybooks

The absence of opposing aftereffects across four groups of 5-year-olds cannot be attributed to a lack of power. First, our method yielded partial transfer of aftereffects across face race. Second, we collectively analyzed the data from Experiment 1a, Experiment 2 (children tested with the original storybook), and Experiments 3a and 3b (n = 96). A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated-measures ANOVA with the change in the number of distorted faces chosen as the dependent variable revealed no main effects or interaction, *p*s > .08, η_p^2s $\leq$ .03, which indicates that the lack of opposing aftereffects was not due to a small sample size.

General Discussion

Collectively, our findings indicate that separable representations of faces belonging to different categories (race, age, sex) is emerging, but not yet mature, at 5 years of age. Caucasian and Chinese children showed attractiveness aftereffects for both own- and other-race faces (Experiment 1b) that partially transferred to the face race not seen during adaptation. This is a significant finding for two reasons. First, it shows that 5-year-olds rely on at least some separable coding dimensions for own- and other-race faces, just as 8-year-olds (youngest age tested) do for upright and inverted faces (Jeffery et al., in press). Second, it confirms that our testing protocol is sufficiently engaging to maintain children's attention and is sensitive to category-specific shifts in face norms (i.e., is capable of detecting differences in the magnitude of aftereffects between two categories, Experiment 1b).

Nonetheless, 5-year-olds' representations of faces belonging to different categories are not sufficiently distinct to drive opposing aftereffects. A possible alternative explanation for the lack of opposing aftereffects is that children simply failed to adapt to our storybook stimuli. However, we do not believe this to be the case for two reasons. First, the same protocol that elicits simple aftereffects and partial transfer thereof in 5-year-olds (Experiment 1b) and opposing aftereffects in 8-year-olds and adults (Short et al., 2011) failed to elicit opposing aftereffects in 5-year-olds, even when children were tested with categories with which they had abundant experience (Experiments 2, 3a, 3b). This suggests that our adapting stimuli are capable of eliciting aftereffects and that our method is sensitive to changes in children's attractiveness preferences. Second, in Experiment 2 (5-year-olds with ample exposure to other-race faces), children did show significant aftereffects in almost all conditions; however, these aftereffects were not specific to adapting condition and instead reflected a general increase in tolerance for all facial distortions. Therefore rather than reflecting a lack of adaptation, it is likely that in each experiment, exposure to oppositely distorted faces simply cancelled each other out, thus producing no net change in attractiveness preferences for either face category.

Our results do not discount the overall role of experience in the refinement of face space. Indeed, the importance of early experience is well established: unlike visually normal adults, adults deprived of early patterned visual input due to bilateral congenital cataracts show no evidence for opposing aftereffects for upright and inverted faces (Robbins et al., 2012). Rather, our results suggest that five years of experience is not sufficient to support the development of separable prototypes.

Our results demonstrate that 5-year-olds' face space is considerably less well refined than that of adults and 8-year-olds. Two potential models may describe the organization of 5-year-olds' face space. Past research (e.g., Jeffery et al., 2010; Jeffery et al., 2013) has shown that children as young as 4 years rely on norm-based coding, at least for own-race faces. With regard to face race, children might use norm-based coding for own-race faces but process other-race faces as individual exemplars. Alternatively, young children might rely on a category-generic prototype. This second model is more plausible because the results of Experiment 1b demonstrate that children show significant aftereffects for other-race faces that are of a comparable magnitude to those for own-race faces. Furthermore, there was significant transfer of aftereffects across face race, which indicates overlap in the coding dimensions used for own- and other-race faces. Lastly, while it is conceivable that children may initially process other-race faces as individual exemplars, this same explanation does not hold true for faces from other categories. It is hard to imagine that children would have a prototype for female faces but process male faces as exemplars. A more parsimonious explanation is that children initially encode all faces with regard to a category-generic prototype that gradually differentiates with age. Such an explanation is consistent with the recent finding that children's biases based on males' and females' attractiveness tend to increase with age (Rennels & Langlois, 2014), which may be due to the development of separable representations for face sex as children progress from early to middle childhood. Among adults, identity aftereffects are larger for adapt-test face pairs that lie opposite to a sex-specific relative to a sex-generic norm (Rhodes et al., 2011; see Armann et al., 2011 for similar findings for face race). We predict that young children may not show this effect, which would provide additional evidence for reliance on a category-generic prototype in early childhood.

A number of factors may drive the development and increased refinement of face space across childhood. Some of this refinement may occur as a function of general cognitive and perceptual development. For example, increases in visual acuity (e.g., improvements in spatial contrast sensitivity; Ellemberg, Lewis, Hong Liu, & Maurer, 1999) may enhance sensitivity to the various dimensions of face space while improvements in working memory allow for a greater number of dimensions to be processed concurrently. Consistent with this viewpoint, children are less sensitive than adults to facial distortions (Anzures et al., 2009; Crookes & McKone, 2009; Jeffery et al., 2010) and to differences in feature spacing not only in human faces (e.g., Mondloch et al., 2002), but also in houses (Robbins, Shergill, Maurer, & Lewis, 2011) and monkey faces (Mondloch, Maurer, & Ahola, 2006). Furthermore, although sensitive to multiple face dimensions, 8-year-olds have difficulty processing these dimensions simultaneously (Nishimura et al., 2009). Collectively, these results suggest that at least some general cognitive/perceptual development underlies increases in the refinement of face space.

Some face-specific development may also drive the increased refinement of face space. In particular, development and increased specialization of face-specific regions in the brain may improve sensitivity to relevant dimensions and even increase the number of dimensions used to process faces of a given category. Adults show a strong right hemispheric bias when processing faces (e.g., Kanwisher, McDermott, & Chun, 1997); however, there is evidence that children show less hemispheric specialization (Anes & Short, 2009; but see de Schonen & Mathivet, 1990) and decreased localization (Passarotti et al., 2003) for face perception than adults. Though present even in young children, the N170 does not become adult-like until early adolescence (de Haan, Pascalis, & Johnson, 2002; Taylor, Batty, & Itier, 2004). Moreover, significant increases in the size and specificity of face-selective cortical brain regions have been found throughout childhood and into adolescence (e.g, Grill-Spector, Golarai, & Gabrieli, 2008), and there is some evidence that regions in the extended face network are hyperactivated regardless of task demands in children relative to adults (Haist, Adamo, Wazny, Lee, & Stiles, 2013). Such findings suggest that face-specific brain regions continue to undergo refinement throughout childhood and may support fine-tuning of the category-specific dimensions of face space.

Young children's decreased reliance on category-specific norms may partially explain their poor performance on some face perception tasks relative to adults. Norm-based coding is thought to facilitate discrimination around the norm (Wilson et al., 2002), and in adults, category-specific prototypes appear to enhance recognition; face identification is better around a race-specific relative to a mixed-race average (Armann et al., 2011). The use of separable norms may be more economical than reliance on a single norm, as faces naturally lie closer to a category-specific relative to a category-generic prototype. Furthermore, relying on separable norms may ensure that only relevant dimensions are used to encode faces from a given category. For example, dimensions that are specific to Chinese faces will not aid in encoding Caucasian faces and a failure to exclude these irrelevant dimensions may increase errors in recognition for Caucasian faces. Future studies should examine whether, like individual differences in the magnitude of figural (Dennett et al., 2012) and identity aftereffects (Rhodes et al., 2014), individual differences in the magnitude of opposing aftereffects correlate with recognition. If a positive correlation is found between the size of opposing aftereffects and recognition accuracy, this would provide additional support for the notion that separable prototypes aid in recognition.

Collectively, our results suggest that although the mechanisms that underlie expert face processing are in place by 5 years of age, considerable refinement of these mechanisms occurs throughout childhood. Weigelt et al. (2014) argue that face perception (which they restrict to the ability to discriminate faces) is mature by 5 years of age because a considerable increase in discrimination threshold between 5 and 10 years of age is also evident for cars, bodies, and scenes. They suggest that only face memory shows domain-specific development. Although we agree that performance on their discrimination task improved similarly across categories, we question equating evidence of domain-general development with maturity. Indeed, we are agnostic about the extent to which the refinement of face space is based on domain-specific development and about the degree to which this refinement reflects development in perception versus memory, although evidence that children are less sensitive than adults to deviations along dimensions (e.g., Anzures et al., 2009) suggests perceptual factors likely play a role. Given that domain-general development contributes significantly to age-related changes in children's ability to recognize facial identity, we recommend that future studies examine which aspects of face processing are refined throughout childhood rather than dismissing any domain-general changes as trivial.

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CHAPTER 4

Study 3: Attentional Allocation and Recognition for Young and Older Faces[6]

Adults are experts in face recognition (Maurer, Le Grand, & Mondloch, 2002); however, this expertise is limited to the face categories with which they have the most experience (e.g., Rhodes, Hayward, & Winkler, 2006). Numerous studies have investigated the cross-race effect whereby other-race faces are categorized more quickly (e.g., Ge et al., 2009) but recognized less accurately (e.g., Hancock & Rhodes, 2008) than own-race faces. This effect has been attributed to differential expertise (e.g., differential sensitivity to differences among faces in the shape of features or the spacing between them; Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010) and to social cognitive factors (e.g., categorizing out-group members versus individuating in-group members; Hugenberg, Young, Bernstein, & Sacco, 2010; Sporer, 2001).

Given the growing population of older adults and the retirement of the baby boomer generation, it is important to understand how face perception varies not only as a function of race but also as a function of participant and face age. Although a wealth of research has investigated the cross-race effect and its implications for daily social interactions, the cross-age effect is inherently more complex and has received much less attention (for a recent review, see Wiese, Komes, & Schweinberger, 2013). Better recognition of own-age faces in young adults is a robust phenomenon (reviewed in Rhodes & Anastasi, 2012). However, the findings for children and older adults are less consistent, with some studies reporting better recognition for own- relative to other-age faces across all participant age groups (e.g., Anastasi & Rhodes, 2005; Perfect & Harris, 2003; Rhodes &

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[6] This chapter is based on a paper that is currently under review: Short, L. A., Semplonius, T., Proietti, V., & Mondloch, C. J. Differential attentional allocation and subsequent recognition for young and older adult faces. *Visual Cognition.*

Anastasi, 2012), and other studies reporting comparable recognition for young adult faces relative to own-age faces among children and older adults (e.g., Fulton & Bartlett, 1991; Wallis, Lipp, & Vanman, 2012; Wiese, Schweinberger, & Hansen, 2008; Wolff, Wiese, & Schweinberger, 2012).

Several factors contribute to the increased complexity of the cross-age effect. First, whereas face race is a stable characteristic, age, and hence the age of faces to which one is exposed, changes across the lifespan; young adults report more exposure to young adult faces whereas senior citizens report more exposure to older adult faces (He, Ebner, & Johnson, 2011). Although recent experience may influence perception (e.g., Wiese, Komes, & Schweinberger, 2012), some theorists (Macchi Cassia, 2011) have argued that abundant experience with young adult faces early in life (Rennels & Davis, 2008) sets up a life-long perceptual bias for young adult faces. Second, whereas studies investigating the cross-race effect rarely report a main effect of participant race (e.g., Megreya, White, & Burton, 2011), children and older adults typically perform worse than young adults in tests of face recognition (Bartlett & Leslie, 1986; Bowles et al., 2009; Hills & Lewis, 2011). In particular, older adults tend to exhibit a high false alarm rate relative to young adults (e.g., Bartlett & Memon, 2007). It is possible that floor effects may account for any failures to detect recognition biases in young children and older adults (Wiese, 2012; see McKone & Boyer, 2006 for a discussion of floor effects in children). Overall differences in accuracy may be attributable to general cognitive factors (e.g., Salthouse, 2004) as well as differential scanning strategies. For example, Firestone, Turk-Browne, and Ryan (2007) found that for both young and older faces, young adults spend more time than older adults looking at the eyes whereas older adults spend more time than young adults looking at the mouth and nose.

Although some studies (e.g., Havard & Memon, 2009; Wright & Stroud, 2002) have asked participants to view mock crime scene videos and later identify the culprit in a lineup, in most studies investigating both the cross-race and cross-age effects, faces are learned in isolation rather than within a naturalistic context (e.g., Anastasi & Rhodes, 2005; Harrison & Hole, 2009; Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008). Such methods fail to mimic how faces are encountered in the real world where multiple faces are encountered simultaneously and compete for attention with each other and with other stimuli (e.g., bodies, objects). The presentation of each face in isolation during learning minimizes participants' opportunity to selectively allocate their attention to one particular category of face (e.g., own-age faces), making it difficult to determine the extent to which age biases affect recognition in everyday life.

The primary goal of the current study was to enrich our understanding of cross-age effects by presenting young and older adult faces in the context of naturalistic scenes (e.g., parks and outdoor shopping centers) and examining both allocation of attention to young versus older faces during learning and the relationship between attentional allocation and subsequent recognition. We tested both young and older adult participants; in our sample, all participants reported significantly more recent contact with own- than other-age individuals. Thus our older adult participants were comparable to the high-contact older adults tested by Wiese et al. (2012) who showed an own-age recognition bias.

During the learning phase, young and older adults' eye movements were recorded as they viewed eight images of natural scenes, each of which included two young and two older adults. We hypothesized that young adults would allocate more attention to own- relative to other-age faces, based on studies showing preferential looking towards own-age faces in young adults even when faces are presented in isolation (Ebner, He, & Johnson, 2011b; Firestone et al., 2007; He et al., 2011) and on studies showing an attentional advantage for own-race relative to other-race faces when faces are presented in scenes (change-blindness paradigm; Humphreys, Hodsoll, & Campbell, 2005) or in pairs comprising an own- and other-race face (Lovén et al., 2012).

We did not make predictions for the allocation of attention among older adults because previous results for older adults are less consistent. Although older adults looked longer at own-age faces than young adult faces in two studies involving a passive viewing task (Ebner et al., 2011b; He et al., 2011), they looked longer at young adult faces when asked to judge the age of individual faces and rate the quality of the images prior to completing a surprise memory task (Firestone et al., 2007). These inconsistent findings for older adults likely reflect the influence of two factors: Whereas older faces may receive preferential attention by virtue of their belonging to a social in-group (Rodin, 1987), young faces may draw attention because they are perceived to be more positive than older faces (as shown by both implicit attributions and explicit age stereotypes; He et al., 2011). Indeed, whereas young and middle-aged young adults perceive themselves as being more closely connected to young than older adults, older adults do not differ with regard to perceived closeness to young and older adults (Wolff et al., 2012).

Following the learning phase, participants completed an old/new recognition task that assessed their memory for the young and older faces in the scenes. We hypothesized that young adults would be more accurate in recognizing own- relative to other-age faces. The cross-age effect is quite robust in young adults and has been consistently demonstrated across a wide range of studies (e.g., Harrison & Hole, 2009; Rhodes & Anastasi, 2012). In contrast, evidence for the cross-age effect is less consistent in older adults (see above); thus we made no specific predictions as to whether older adults would show an own-age bias in recognition.

We also examined whether differences in attentional allocation during learning influence the magnitude of the cross-age effect. Ebner et al. (2011b) found that longer looking at own- relative to other-age faces was correlated with improved emotional expression identification for own-age faces. Likewise, He et al. (2011) reported that the own-age bias in the visual inspection of individually presented faces was correlated with the magnitude of the other-age effect in recognition. However, not all studies have found evidence for this correlation; Firestone et al. (2007) found that visual scan patterns on own- and other-age faces were not associated with performance on a subsequent old/new recognition task. In the current study, young and older faces were simultaneously presented and thus we expected that the longer the participants looked at own-age faces, the less time they had to extract the relevant identifying information from other-age faces. This lack of knowledge about the other-age faces presented in the scenes would make these faces more difficult to recognize in the subsequent memory task. Thus we hypothesized that looking time for young and older faces and the magnitude of an own-age bias in looking time would correlate with accuracy for young and older faces and the magnitude of an own-age bias in recognition memory, respectively.

The second goal of the current study was to systematically examine whether participants' goals during learning influence scanning strategies and affect subsequent recognition. Scene perception involves both bottom-up and top-down processing, and task knowledge appears to influence both scan patterns over a scene and gaze duration (reviewed in Henderson, 2011). There is evidence that goals influence the allocation of attention. For example, Kaakinen, Hyönä, and Viljanen (2011) showed participants scenes of interior home settings and asked them to examine the images from the perspective of a homeowner, a burglar, or in preparation for a memory test. Participants in the homeowner and burglar conditions looked longer and more frequently at perspective-relevant items whereas those in the memory condition looked longer and more frequently at the most salient items in each setting. Likewise, allocation of attention when viewing a painting of several people in a room varies by task instructions (DeAngelus & Pelz, 2009; Yarbus, 1967). Although Rhodes and Anastasi (2012) report that intentional versus incidental encoding at learning does not moderate the magnitude of the cross-age effect in recognition when faces are presented individually, we hypothesized that both recognition and allocation of attention when faces are presented in naturalistic scenes may be influenced by participants' goals. To this end, half of the participants were instructed to form a general impression of the people in each scene and half were explicitly told that they would be asked to recognize the people they viewed in each scene. The impressions condition was designed to draw participants' attention to the people in the scenes without alerting them to the subsequent memory task (i.e., an incidental learning condition), whereas the memory condition was designed to encourage participants to rely on specific memory strategies to aid in recognition (i.e., an intentional learning condition). Thus whereas the memory condition taps more directly into face recognition ability when participants are motivated to remember, the impressions condition may better represent how faces are naturally viewed in everyday life.

We hypothesized that providing participants with the knowledge that they would later be asked to recognize the people in the scenes would increase motivation to attend to all faces in each image; thus we expected that regardless of participant and face age, participants in the memory condition would spend more time looking at faces than those in the impressions condition. Furthermore, we expected that participants in the impressions condition would spend more time looking at the bodies and scene context than those in the memory condition. Lastly, we expected that regardless of participant age, participants in the memory condition would be more accurate in recognizing faces and show a smaller cross-age effect than those in the impressions condition.

Method

Participants

Forty Caucasian undergraduate students from Brock University (36 female; *M* = 19.40 years, age range = 18-24) and 40 Caucasian senior citizens living in independent housing in the Niagara region of Ontario (31 female; *M* = 69.53, age range = 57-84) participated in this experiment. Senior citizen participants were all in good health, and 39 of the 40 senior participants had 20/30 vision or better. Undergraduates received research credit or a small honorarium and senior citizens received a gift card for their participation in the study. Participants completed a questionnaire assessing their weekly face-to-face contact with young and older adults (see Appendix 4). Both groups reported spending more time with own-age peers (*M* = 57.00 hours and 46.83 hours per week for young and older adults, respectively) than other-age individuals (*M* = 4.35 and 5.59 hours per week). Furthermore, 90% of the seniors in our sample indicated that they lived alone or with another senior only. An additional 19 participants were tested but excluded from the final data set due to equipment malfunction (n = 3 young adults, 1 older adult) or because participants' (n = 15 older adults) eye movements failed to meet criterion (defined as ≥ 70% of gaze data recorded from both eyes during the learning phase).

Materials

Learning phase. Stimuli consisted of eight colored photographs of natural settings such as parks, outdoor shopping centers, and streetscapes. Each photograph was resized such that the width was 1280 pixels and the height was 900 pixels. We used Adobe Photoshop version CS5 to alter the photographs such that faces were superimposed onto same-age bodies of the people in the scenes (Figure 4.1). Face stimuli were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) and resized such that each face realistically fit the young or older body to which it was attached. Each photograph included two forward-facing young adults (face age range = 19-26 years) and two forward-facing older adults (face age range = 70-85 years); thus there was a total of 32 faces (16 young) that were to be later recognized. Half of the faces in each age category were female. Scenes were presented using Tobii Studio 3.2 and eye movements were recorded by a Tobii T60 XL Eye Tracker (approximately 0.5 degrees of precision, 24 inches, 60 Hz sampling rate, 1440 x 900 pixels resolution). Across all eight scenes, the percentage of the screen occupied by the young adult faces (12%) was

Figure 4.1. Sample scene shown during the learning phase. Each scene contained two young and two older adult faces.

identical to the percentage of the screen occupied by the older adult faces (12%). Furthermore, in a pilot test, we validated that young and older adults were viewed as equally central to the scenes by blurring the faces such that all age-identifying facial information was removed. Pilot participants (n = 10 young adults; 4 female) were asked to indicate the two people in each scene who they viewed as most central to the action. Across all eight scenes, there was no difference in the extent to which young and older adult bodies were indicated as central to the scene, $p = .13$.

Test phase. Both familiar and novel test stimuli consisted of colored photographs of Caucasian young (age range = 19-26 years) and older adult (age range = 70-89 years) faces. All stimuli were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) and resized such that the distance from hairline to chin was approximately 250 pixels. All background information (e.g., clothing) was digitally removed using Adobe Photoshop version CS5 and faces (including hair) were placed on a white background. Half of the faces (16 from each age category) were previously shown during the learning phase and half were novel; thus 64 faces (32 female) were shown during the test phase. Both familiar and novel faces were previously rated by 12 young adults (8 female) on a 7-point attractiveness scale (1 = not at all attractive, 7 = extremely attractive) and by 13 separate female young adults on a 7-point distinctiveness scale (1 = not at all distinctive, 7 = extremely distinctive). In this rating task, participants were asked to rate the attractiveness of each face with regard to other faces from the same age group and to judge the distinctiveness of each face based on how likely the face would stand out in a crowd. Young adult faces received a mean rating of 3.72 ($SD = .69$) on attractiveness and 3.69 ($SD = .36$) on distinctiveness. Older adult faces received a mean rating of 3.46 (*SD* = .54) on attractiveness and 3.81 (*SD* = .48) on distinctiveness. There were no significant differences between young and older adult faces in either attractiveness, $t(62) = -1.64$, $p = .11$, or distinctiveness, $t(62) = 1.13$, $p = .26$. All faces were presented and responses were recorded in the recognition task using E-Prime software.

Procedure

The procedure received clearance from the Research Ethics Board at Brock University, and participants gave written consent prior to their participation. Upon arrival to the lab, participants were seated approximately 65 cm in front of a 24-inch Tobii Eye Tracker. Before beginning the experiment, participants' eye movements were calibrated using a 5-point fixation procedure. Following the calibration, participants were told one of two sets of instructions before beginning the learning phase. Half of the participants were explicitly told that they would later be asked to identify the people they viewed in the scenes, whereas the other half were told to form an impression of the people shown in the scenes. In both instruction conditions, each scene was shown for 40 seconds and was preceded by a 1-second fixation cross in the center of the screen. We elected to show each scene for 40 seconds based on pilot testing and to be consistent with other work examining attentional allocation to own- and other-race faces presented in complex scenes (Semplonius & Mondloch, in preparation). The order in which the scenes were presented was randomized across participants.

After viewing the eight scenes, participants were told that they would be shown a series of individual faces and that their task was to indicate whether each face was novel or familiar as quickly and as accurately as possible. Faces were presented on the eye-tracking monitor but eye movements were not recorded. Each trial consisted of a 500-ms fixation cross, followed by a face that remained on the screen until a response was made. Participants indicated their response by pressing the z or m key on a keyboard; for half of the participants, the z key indicated that the face was familiar and the m key indicated that the face was novel, and for the other half, key assignment was reversed. The order in which the faces were presented was fully randomized for each participant, and there was a total of 64 trials in the test phase.

Results

Learning Phase

All eye-tracking data were obtained from the Tobii Studio software. For each scene, we defined four key areas of interest (two young adult face AOIs and two older adult face AOIs). These four AOIs were then collapsed across the eight scenes into two AOI groups: young adult faces and older adult faces. To investigate whether participants' attentional allocation differed for young and older faces, we examined two key variables of interest: total visit duration, which provides a measure of the amount of time participants spent looking at each AOI group summed across all visits, and visit count, which provides a measure of the number of times participants looked at each AOI group. We conducted 2 (face age: young adult, older adult) x 2 (participant age: young adult, older adult) x 2 (instruction type: impressions, memory) mixed ANOVAs to examine whether the amount of time (in seconds) spent visiting young and older faces and the frequency with which each face age was visited varied depending on participant age and instruction type.

Total visit duration. Both participant age groups spent more time visiting young (M = 68.09, SE = 3.63) than older (M = 57.39, SE = 3.27) adult faces, as shown by a main effect of face age, $F(1, 76) = 56.93$, $p < .001$, $\eta_p^2 = .43$ (see Figure 4.2). There was also a main effect of participant age, $F(1, 76) = 36.14$, $p < .001$, $\eta_p^2 = .32$; young adults spent more time visiting faces (M = 79.05, SE = 4.54) than older adults (M = 46.43, SE = 3.46). There was a main effect of instruction type, $F(1, 76) = 8.65$, $p = .004$, $\eta_p^2 = .10$. Participants in the memory group spent more time visiting faces (M = 70.72, SE = 5.01) than those in the impressions group (M = 54.76, SE = 4.23).

The main effects of face age and instruction type were qualified by a face age by instruction type interaction, $F(1, 76) = 6.49$, $p = .01$, $\eta_p^2 = .08$. In the memory group, more time was spent visiting young faces (M = 77.88, SE = 5.41) than older faces (M = 63.56, SE = 4.84), $t(39) = -6.46$, $p < .001$, Cohen's d = .44. Likewise, in the impressions group, more time was spent visiting young faces (M = 58.31, SE = 4.40) than older faces (M = 51.22, SE= 4.25), $t(39) = -3.82$, $p < .001$, Cohen's d = .26. Thus, the same pattern of results was found in the two instruction types, but the effect size was larger for participants in the memory group. All other two- and three-way interactions did not reach significance, ps > .08.

Visit count. Similar to total visit duration, there were more visits to young (M = 79.16, SE = 2.59) than older (M = 73.95, SE = 2.68) faces for both age groups, as shown by a main effect of face age, $F(1, 76) = 16.17$, $p < .001$, $\eta_p^2 = .18$. There was also a main effect of participant age, $F(1, 76) = 13.68$, $p < .001$, $\eta_p^2 = .15$; young adults made overall more visits to faces (M = 85.15, SE = 3.04) than older adults (M = 67.96, SE = 3.62). There was a main effect of instruction type, $F(1, 76) = 4.71$, $p = .03$, $\eta_p^2 = .06$.

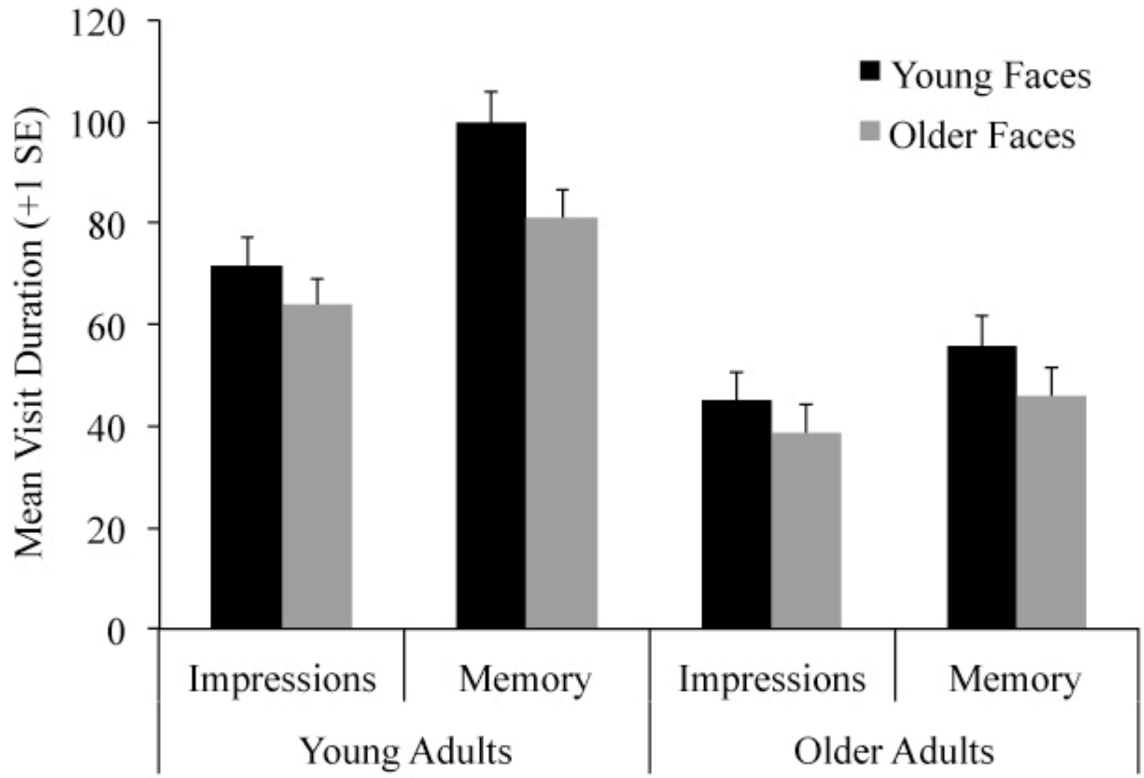

Figure 4.2. Mean visit duration (+1 SE) for young and older faces for both participant age groups in each instruction condition.

Participants in the memory group made more visits to faces (*M* = 81.60, *SE* = 3.54) than those in the impressions group (*M* = 71.51, *SE* = 3.51).

The main effects of face age and instruction type were qualified by a face age by instruction type interaction, $F(1, 76) = 4.96$, $p = .03$, $\eta_p^2 = .06$. In the memory group, there were more visits to young (*M* = 85.65, *SE* = 3.47) than older adult faces (*M* = 77.55, *SE* = 3.85), $t(39) = -4.22$, $p < .001$, Cohen's $d = .35$. However, in the impressions groups, the number of visits to young faces (*M* = 72.68, *SE* = 3.60) did not differ from the number of visits to older faces (*M* = 70.35, *SE* = 3.67), $t(39) = -1.23$, $p = .23$, Cohen's $d = .10$. There was also a significant face age by participant age interaction, $F(1, 76) = 7.77$, $p = .007$, $\eta_p^2 = .09$. Among young adults, the number of visits to young faces (*M* = 85.95, *SE* = 3.01) did not differ from the number of visits to older faces (*M* = 84.35, *SE* = 3.35), $t(39) = -.86$, $p = .40$, Cohen's $d = .08$. However, among older adults, there were more visits to young (*M* = 72.38, *SE* = 3.96) than to older faces (*M* = 63.55, *SE* = 3.50), $t(39) = -4.70$, $p < .001$, Cohen's $d = .37$. Neither the participant age by instruction type interaction nor the three-way interaction reached significance, *p*s > .57.

First 10 seconds of each scene. To examine whether young adult faces received a large attentional advantage during the initial encoding of the scenes, we analyzed both total visit duration and visit count during the first 10 seconds of each scene. Similar to the full 40 seconds of presentation, both age groups spent more time visiting young (*M* = 2.39, *SE* = .14) than older (*M* = 1.92, *SE* = .13) faces, as shown by a main effect of face age, $F(1, 76) = 8.73$, $p = .004$, $\eta_p^2 = .10$. There was a main effect of participant age, $F(1, 76) = 10.49$, $p = .002$, $\eta_p^2 = .12$; young adults spent more time visiting faces (*M* = 2.51, *SE* = .15) than older adults (*M* = 1.81, *SE* = .15). There was also a main effect of instruction type, $F(1, 76) = 6.77$, $p = .01$, $\eta_p^2 = .08$. Participants in the memory group spent more time visiting faces ($M = 2.44$, $SE = .15$) than those in the impressions group ($M = 1.87$, $SE = .15$). Unlike the full 40 seconds of presentation, there was no face age by instruction type interaction, $p = .30$; however, there was a participant age by instruction type interaction, $F(1, 76) = 5.74$, $p = .02$, $\eta_p^2 = .07$. Among young adults, participants in the memory group spent more time visiting faces ($M = 3.04$, $SE = .20$) than those in the impressions group ($M = 1.97$, $SE = .19$), $t(38) = -3.92$, $p < .001$, Cohen's $d = 1.26$. However, among older adults, there was no difference in overall time spent visiting faces across both instruction types ($M = 1.83$, $SE = .27$ and $M = 1.78$, $SE = .20$ for the memory and impressions groups, respectively), $t(38) = -.13$, $p = .89$, Cohen's $d = .05$.

In terms of visit count, there was only a main effect of participant age, $F(1, 76) = 5.59$, $p = .02$, $\eta_p^2 = .07$; young adults made more visits to faces ($M = 3.96$, $SE = .24$) than older adults ($M = 3.18$, $SE = .24$). There was also a face age by instruction type interaction, $F(1, 76) = 3.96$, $p = .05$, $\eta_p^2 = .05$. However, follow-up t-tests revealed that the number of visits to young faces did not differ from the number of visits to older faces for either instruction type, ps > .15.

Total visit duration for non-face items in the scenes. To determine whether any differences in looking time were face-specific, we examined whether there were group differences in how much time was spent looking at young and older adult bodies in the scenes. We conducted a 2 (body age: young adult, older adult) x 2 (participant age: young adult, older adult) x 2 (instruction type: impressions, memory) mixed ANOVA to examine whether the amount of time spent visiting young and older bodies varied as a function of participant age and instruction type. There was a main effect of body age,

$F(1, 76) = 18.94$, $p < .001$, $\eta_p^2 = .20$, such that young bodies were looked at longer (M = 36.36, SE = 1.86) than older bodies (M = 32.25, SE = 1.68). All other main effects and interactions were not significant, ps > .15[7].

We also examined whether there were group differences in the amount of time spent looking at the context of the scene (i.e., entire scene excluding the faces and bodies) to verify that our task instructions were effective (i.e., that the impressions group spent more time than the memory group looking at the background scene) and to ensure that participants remained on-task and that the eye tracker was able to consistently track their eye movements. A 2 (participant age: young adult, older adult) x 2 (instruction type: impressions, memory) univariate ANOVA revealed a main effect of participant age, $F(1, 76) = 44.41$, $p < .001$, $\eta_p^2 = .37$; older adults spent more time visiting the scene context (M = 136.94, SE = 6.46) than young adults (M = 83.83, SE = 5.12). There was also a main effect of instruction type, $F(1, 76) = 7.41$, $p = .01$, $\eta_p^2 = .09$; participants in the impressions group spent more time visiting the scene context (M = 121.23, SE = 6.93) than those in the memory group (M = 99.54, SE = 7.08). The interaction of participant age by instruction type was not significant, $p = .69$.

Test Phase

Recognition accuracy. To provide an unbiased measure of participants' recognition memory for young and older adult faces, we calculated each participant's *d′* for both face ages using Macmillan and Creelman's (1991) method. Our analyses focused on *d′* and criterion (*C*), but hit and false alarm values are presented in Table 4.1. Single-

[7] We elected to examine only total visit duration for non-face items in the scenes as visit duration was our primary variable of interest and best reflected how much time was spent attending to any given stimulus.

Table 4.1
Means and SEs of test phase.

	Young adults		Older adults	
	Young faces	Older faces	Young faces	Older faces
Hits	9.28 (0.51)	8.05 (0.38)	8.35 (0.53)	7.60 (0.42)
False alarms	2.62 (0.31)	4.43 (0.41)	5.77 (0.54)	5.45 (0.44)
d′	1.31 (0.13)	0.67 (0.10)	0.49 (0.09)	0.40 (0.07)
C	0.04 (0.01)	0.03 (0.01)	0.02 (0.01)	0.03 (0.01)

sample *t*-tests showed that d' values for young and older faces were greater than 0 for all combinations of participant age groups and instruction types, all *p*s < .006. We then conducted a 2 (face age: young adult, older adult) x 2 (participant age: young adult, older adult) x 2 (instruction type: impressions, memory) mixed ANOVA to examine whether recognition for young and older faces varied as a function of participant age and instruction type. There was a main effect of face age, $F(1, 76) = 17.21$, $p < .001$, $\eta_p^2 = .19$; young faces ($M = .90$, $SE = .09$) were recognized more accurately than older faces ($M = .54$, $SE = .06$). There was also a main effect of participant age, $F(1, 76) = 24.16$, $p < .001$, $\eta_p^2 = .24$; young adults showed better recognition memory ($M = .99$, $SE = .09$) than older adults ($M = .45$, $SE = .06$) for all faces collapsed across face age. Among older adults, there was no correlation between vision and overall d' values, $r = .15$, $p = .35$, indicating that older adults' reduced performance was unrelated to any potential age-related deficits in visual acuity. There was no main effect of instruction type, $p = .29$.

Only young adults showed evidence for an own-age recognition advantage. As shown in Figure 4.3, there was a significant face age by participant age interaction, $F(1, 76) = 10.15$, $p = .002$, $\eta_p^2 = .12$. Among young adults, young faces ($M = 1.31$, $SE = .13$) were recognized more accurately than older faces ($M = .67$, $SE = .10$), $t(39) = -4.76$, $p < .001$, Cohen's $d = .87$. However, among older adults, there was no difference in recognition accuracy for young ($M = .49$, $SE = .09$) and older faces ($M = .40$, $SE = .07$), $t(39) = -.77$, $p = .45$, Cohen's $d = .17$. These results are consistent with young adults making more hits and fewer false alarms for young compared to older faces whereas both hit and false alarm rates were higher for young than older faces among older adults (see Table 4.1). Neither the face age by instruction type interaction nor the participant age by

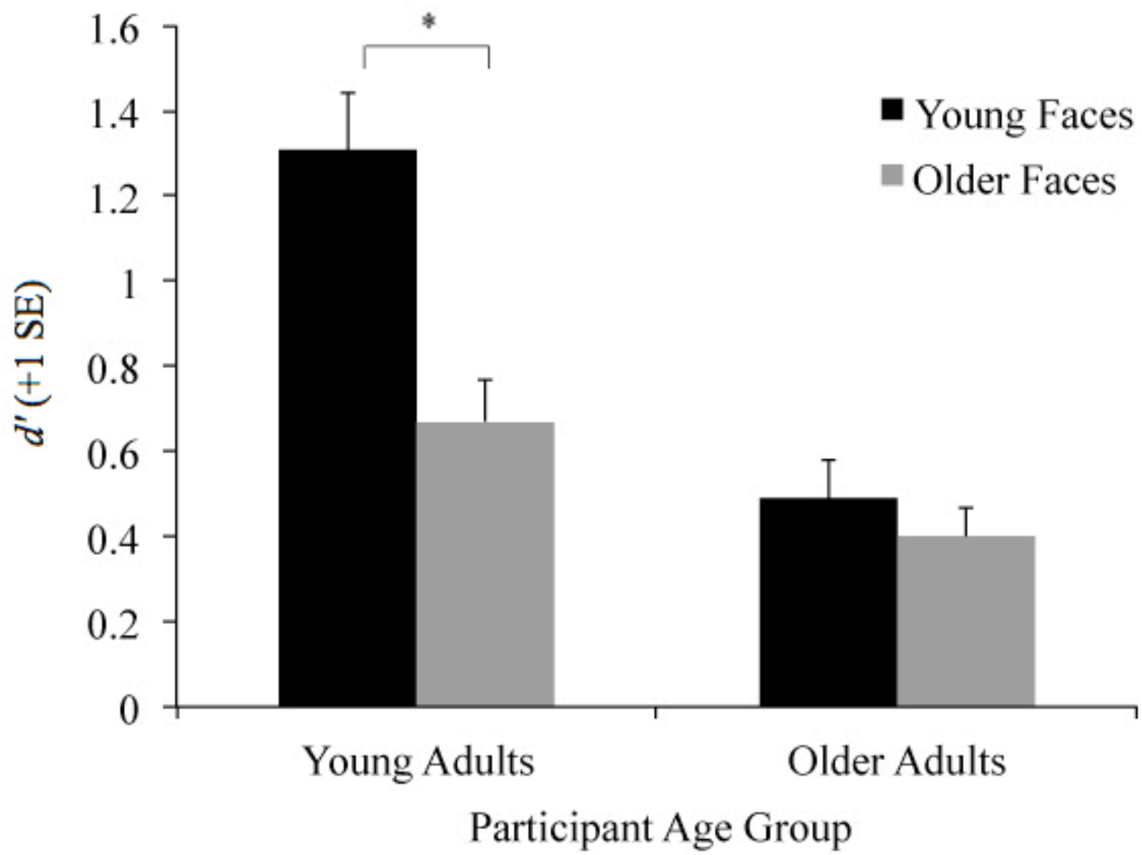

Figure 4.3. Mean *d'* values (+1 SE) for young and older faces shown in the recognition task for both young and older adult participants. Performance was greater than chance in all conditions, and the asterisk indicates that $p < .001$.

instruction type interaction reached significance, *p*s > .08. Lastly, there was no significant three-way interaction, $p = .73$.

To ensure that the lack of any face age biases in older adults was not due to their reduced performance on the memory task relative to young adults, we calculated a corrected memory bias score ((d' [young faces] – d' [older faces])/ |(d' [young faces] + d' [older faces])|; see Wiese et al., 2012) for each participant. Young adults showed a significant positive memory bias, $t(39) = 3.23$, $p = .002$, indicating a young adult face recognition advantage. In contrast, older adults did not show a significant memory bias in either direction, $t(39) = .70$, $p = .49$.

Response bias. To examine participants' response biases, we calculated each participant's criterion (*C*) for both young and older faces using Macmillan and Creelman's (1991) method. A 2 (face age: young adult, older adult) x 2 (participant age: young adult, older adult) x 2 (instruction type: impressions, memory) mixed ANOVA revealed a marginally significant main effect of participant age, $F(1, 76) = 3.75$, $p = .06$, $\eta_p^2 = .05$, such that young adults tended to be more conservative in their responses ($M = .04$, $SE = .01$) than older adults ($M = .02$, $SE = .01$). There was also a marginally significant main effect of instruction type, $F(1, 76) = 3.55$, $p = .06$, $\eta_p^2 = .05$; participants in the impressions group tended to be more conservative in their responses ($M = .04$, $SE = .01$) than participants in the memory group ($M = .02$, $SE = .01$). There were no other main effects or interactions, all *p*s > .13.

Relationship between Looking Time and Recognition

To determine whether there was a relationship between participants' looking time and subsequent recognition memory, we examined whether there was a correlation between total visit duration for own-age faces and d' for own-age faces for both young and older adult participants. We also examined whether there was a correlation between total visit duration for other-age faces and d' for other-age faces for both participant age groups. Among young adults, there was no relationship between looking time and d' for either own-age faces, $r = .27$, $p = .09$, or other-age faces, $r = .08$, $p = .61$. Likewise, among older adults, there was no relationship between looking time and d' for either own-age faces, $r = .07$, $p = .66$, or other-age faces, $r = -.12$, $p = .44$.

To further confirm the lack of a relationship between looking time and recognition, we calculated the magnitude of the own-age looking time advantage by subtracting total visit duration on other-age faces from total visit duration on own-age faces for each participant. We then calculated the magnitude of the own-age recognition advantage by subtracting d' for other-age faces from d' for own-age faces for each participant. A moderated regression was conducted to examine whether the relationship between the own-age looking time advantage (centered) and own-age recognition advantage was moderated by participant age, task instruction, or any of the two- or three-way interactions between the three predictors. Overall, the model was significant, *Adjusted* $R^2 = .13$, $F(7, 72) = 2.66$, $p = .02$. However, the only significant predictor in this model was participant age, $\beta = -.43$, $p = .004$; young adults showed a larger own-age recognition advantage than older adults. All other predictors and interactions between the predictors were not significant, *p*s > .47[8].

[8] Given that we found evidence for a young adult looking time advantage for both participant age groups, we conducted this same analysis to examine whether there was a relationship between a young adult looking time advantage and a young adult recognition advantage. The overall model was not significant, *Adjusted* $R^2 = .06$, $F(7, 72) = 1.69$, $p = .13$, but there was a significant predictor of participant age, $\beta = -.32$, $p = .007$; young adults showed a larger young adult recognition advantage than older adults.

Discussion

The primary goal of the present study was to examine the effect of participant age on attentional allocation and subsequent recognition for young and older faces learned within the context of naturalistic environments. Although our study was not designed to disentangle perceptual expertise and social cognitive accounts of the cross-age effect, we briefly discuss our findings with regard to each of these models. A second goal was to determine whether task instructions (remembering versus forming impressions of the people in the scenes) would influence these effects.

Attentional Allocation for Young and Older Faces

Overall, both young and older adults attended more to young than older faces during the learning phase. This was demonstrated by longer total visit duration and by more visits to young than older faces, although the latter pattern was evident only for older adult participants. Differential attentional allocation to young versus older faces cannot be attributed to differences in the salience or the amount of space occupied by young and older faces. Across all scenes, both face ages occupied the same percentage of the screen and our pilot task revealed that young and older adults were viewed as equally central to the action of the scenes.

The pattern of results for young adult participants is consistent with both social cognitive and perceptual expertise accounts of the cross-age effect. Young adults may be motivated to attend more to in-group (i.e., young adult) faces and disregard the faces of out-group (i.e., older adult) members (Rodin, 1987), and for this reason they may develop strategies that are more finely tuned for the processing and recognition of own-age faces. For example, young adults may be more sensitive to subtle differences across young than older adult faces, which may aid them in extracting relevant identifying information that can later be used for recognition. Furthermore, according to social cognitive accounts (e.g., Bernstein, Young, & Hugenberg, 2007; Hugenberg et al., 2010; Sporer, 2001), in-group faces are processed at an individual level whereas out-group faces are processed at the categorical level. Individuation likely requires greater effort than categorization (Ge et al., 2009) and thus the pattern of increased attention to young relative to older adult faces may reflect these differential processing strategies.

Although the evidence for young adults is consistent with the literature, older adults' preferential attention to young relative to older faces is inconsistent with social cognitive accounts of the cross-age effect. However, it is important to note that not all researchers have found evidence for older adults attending more to own- relative to other-age faces (e.g., Firestone et al., 2007). One potential explanation that may underlie older adults' longer looking at young relative to older faces is that the older faces were viewed more negatively than the young faces. He and colleagues (2011) found that both young and older adult participants have more positive implicit associations and explicit stereotypes for young than older adult faces (see also Ebner, 2008). Importantly, however, He et al. (2011) did not find that implicit associations and explicit stereotypes predicted the own-age bias or were related to looking time. Additional research has demonstrated that age-stereotypic attitudes tend to be found more often among young relative to older adult raters (Gluth, Ebner, & Schmiedek, 2010; Kite, Stockdale, Whitley, & Johnson, 2005), indicating that older adults are less likely to hold stereotypes against either young or older adults, perhaps because they were once young adults themselves. Regardless of the mixed evidence in the literature, our results clearly indicate that older adults demonstrate a visual preference for young relative to older faces. Given that we did not measure participants' social attitudes, future work should examine the extent to which the visual preference for young adult faces is mediated by age-stereotypic implicit attitudes (such as through the use of the Implicit Association Task; see Wiese, Wolff, Steffens, & Schweinberger, 2013).

It is important to note that young adults spent more time than older adults looking at faces (collapsed across face age), whereas older adults looked longer at the background context, even when explicitly instructed to memorize the people in the scenes. For the purposes of the current task, older adults' looking strategy was less effective than that of young adults, which may explain their reduced performance on the subsequent recognition task relative to young adults. For example, in the memory condition, older adults may have encoded background items alongside the faces as a cue for recognition; however, such items were not shown in the recognition task and thus would not have benefited participants. There is some evidence that older adults rely more on gist-based memory representations than young adults (Koutstaal & Schacter, 1997). This reliance on gist-based memory may be reflective of a tendency to focus on global contextual cues rather than detailed local cues. Accordingly, in the present task, older adults may have taken a more holistic approach to viewing the scenes, which negatively influenced their recognition for the faces when such contextual cues were removed. Older adults' approach to viewing the scenes may also be reflective of age-related changes in emotional regulation and resource allocation. Older adults tend to allocate greater attention to positive than neutral stimuli (reviewed in Mather & Carstensen, 2005). In the current study, all faces were of a neutral valence, and it is possible that older adults perceived the background context to be more positive and emotionally rewarding than the faces (e.g., several scenes depicted exciting parks or street fairs); thus they may have been more apt to attend to the scene context than the face stimuli, regardless of task instructions. Older adults may have also spent more time looking at the background scene relative to young adults because of deficits in visual attention. There is some evidence to suggest that older adults are less successful than young adults in avoiding attentional capture by irrelevant distractor items (Colcombe et al., 2003; but see Madden, 2007). Thus even when older adults were told that their task was to remember the people in the scenes, they may have had difficulty ignoring the details of the background context. Future work should examine face recognition when faces at test are presented in the context in which they were learned, which may particularly benefit older adults' recognition.

Recognition Accuracy for Young and Older Faces

Results from the recognition phase support our hypothesis that young adults would be more accurate in recognizing own- relative to other-age faces. This finding is consistent with the results of past studies that have found an own-age recognition advantage among young adults (Bäckman, 1991; Proietti, Pisacane, & Macchi Cassia, 2013) and supports recent evidence that young adults show greater neural activation in response to young relative to older faces (Ebner, He, Fichtenholtz, McCarthy, & Johnson, 2011a; Wiese et al., 2008). The novelty of this work is that, in contrast to previous studies, faces were displayed within the context of a naturalistic environment, presented with full bodies, and shown in direct competition with another face category. Within this setting that closely mimics the way in which faces are encountered in everyday life, young adults continued to show enhanced recognition for young relative to older faces, which demonstrates the robustness of the own-age bias in young adults across experimental paradigms.

In contrast to young adults, older adults did not show a recognition advantage for own-age faces; rather, they showed comparable recognition accuracy for young and older faces. This is not the first study to fail to find an own-age recognition advantage in an older adult sample (e.g., Bartlett & Leslie, 1986; Fulton & Bartlett, 1991; Wiese et al., 2008). Although our study was not designed to disentangle the effects of recent versus cumulative life experience, the lack of an own-age recognition advantage in older adults may be related to the early and cumulative experience they have received with young adult faces. Although older adults receive extensive recent experience with individuals belonging to their in-group (i.e., other older adults), they were young adults earlier in development and therefore have gathered substantial experience with young adult faces as well. It may be the case that early and continuous exposure to young adult faces throughout development tunes the perceptual system to the dimensions of young adult faces (Short & Mondloch, 2013) and is sufficient to support the recognition of young faces even in older adulthood when young faces are less frequently encountered and are those of a social out-group. Thus, among older adults, recent experience with older faces may enhance recognition abilities for own-age faces; however, the cumulative life experience they have received with young faces still exerts influence and therefore recognition is comparable for the two face ages. Consistent with this is Wiese et al.'s (2008) finding that young adults showed better recognition and a higher-amplitude N250 for own-age than older adult faces, whereas older adults' recognition accuracy and N250 amplitude did not differ as a function of face age. However, it is important to note that a recent study (Wiese et al., 2012) found that older adults who report high contact with other older adults show an own-age recognition advantage whereas those who report low contact with older adults do not. The older adults in our study reported more contact with older than young adults yet did not show an own-age recognition advantage, which is inconsistent with Wiese et al.'s (2012) recent finding.

From a motivational point of view, recent studies have suggested that older adults show more positive explicit stereotypes for younger than older people (He et al., 2011), perceive themselves as equally close to young and older adults (Wolff et al., 2012), and fail to show an in-group bias in trait attributions for young and older individuals (Kite et al., 2005). Given that they themselves were once young, older adults may continue to positively appraise and identify with young adults, which may increase their attention to young faces and ensure continued meaningful experience with young faces. Such experience may thus prevent a loss in recognition accuracy for young adult faces even later in life.

Relationship between Looking Time and Recognition Accuracy

Although both young and older adults looked preferentially towards young adult faces, we did not find any evidence that longer looking times improved recognition. First, older adults did not recognize young adult faces more accurately than older adult faces. Second, there was no relationship between total looking times and recognition accuracy for either young or older faces, and individual differences in the magnitude of the looking time advantage for own-age faces did not predict individual differences in the magnitude of the own-age recognition advantage. Lastly, explicit instructions to remember the faces did not improve recognition performance relative to instructions that simply encouraged participants to form impressions of the scenes.

Our results suggest that memory encoding occurs quite automatically and that longer looking does not necessarily indicate that faces are encoded at a deeper level. It may be that the type of processing we engage in during initial encoding is more important for subsequent recognition than the overall amount of time spent looking at the face. Behaviorally, both young and older adults show evidence for greater holistic processing for young than older faces (Wiese, Kachel, & Schweinberger, 2013), and there is evidence that early electrophysiological components associated with face processing are sensitive to differences in face age. For both young and older adults, the N170 is larger for older versus young adult faces (e.g., Ebner et al., 2011a; Wiese et al., 2008; Wiese et al., 2012) and the P2 is larger for young than older adult faces (Wiese, 2012; Wiese et al., 2008; Wiese et al., 2012). Such differences are suggestive of potentially different encoding strategies for young and older adult faces.

Moreover, recognition can be supported following minimal exposure times and does not require long prolonged visual inspection. The N250r, which is sensitive to face repetition and familiarity, emerges as early as 180 to 220 ms after stimulus onset (reviewed in Schweinberger, 2011; Zheng, Mondloch, & Segalowitz, 2012), and both children and adults can accurately discriminate faces that differ only in the shape of individual features and the spacing among them after a 200-ms presentation time (Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Le Grand, & Maurer, 2002). A significant amount of information can thus be extracted from faces within 1000 milliseconds of exposure; increased looking with no changes in processing strategy may not necessarily provide additional information that benefits recognition. Consistent with this idea is the finding that face recognition is supported by only two fixations at test; more than two fixations does not provide any additional performance benefit (Hsiao & Cottrell, 2008), at least when participants are asked to simply recognize a face in an old/new paradigm.

Effect of Task Instructions

The second goal of the present study was to investigate whether participants' goals during learning influence visual scanning strategies and affect subsequent recognition. Past studies have demonstrated that task instructions can successfully influence participants' allocation of attention (DeAngelus & Pelz, 2009; Kaakinen et al., 2011). Our results are consistent with the literature; participants directed their attention to items in the scenes that were most relevant to their assigned task. For example, participants in the impressions condition took a global approach to examining the scenes and allocated more attention to the scene context relative to those in the memory condition. In contrast, participants in the memory group directed more attention towards faces and less attention towards the background context.

Contrary to our predictions, instructing participants to remember the faces in each scene did not reduce differential allocation of attention to young versus older adult faces. Rather, participants in the memory group showed larger differences in looking time between young and older faces than participants in the impressions group and only the memory group visited young faces more frequently than older faces. Although greater attention was directed toward faces in the memory condition, memory for faces was not better in the memory group than the impressions group. Furthermore, participants in the memory condition did not show a smaller cross-age effect than those in the impressions condition, indicating that although the task instructions were successful in altering scanning patterns, they did *not* alter participants' recognition accuracy for young and older faces (contrasting Kaakinen et al., 2011). These results are consistent with the results of a recent meta-analysis (Rhodes & Anastasi, 2012) that demonstrated that intentional and incidental encoding at learning did not moderate the magnitude of the cross-age effect in recognition. In the current study, our manipulation of task instructions (memory versus impressions) may have more closely mapped onto intentional (memory condition) and incidental (impressions condition) encoding than onto Kaakinen et al.'s strategy of manipulating participants' perspectives during a recognition task. Moreover, our finding that instruction type influenced looking time but not recognition is consistent with our failure to find a relationship between looking time and recognition accuracy; it may be the case that the conditions that affect looking times at learning do not necessarily affect recognition to the same degree.

Conclusions

The strength of the present study rests in its method, which is more ecologically valid than that which has typically been used to test face recognition. Several past studies simultaneously presented young and older faces in brief video clips (e.g., Havard & Memon, 2009; Wright & Stroud, 2002); however, in each of these studies faces were shown in the context of mock crime scenes, which are emotionally arousing situations that do not mimic how faces are encountered in everyday life settings. To our knowledge, this is the first task in which young and older faces were simultaneously presented within realistic, everyday environments and competed for attention with one another and with complex background scenes. Thus we are the first to show how young and older adults selectively allocate their attention in the context of everyday scenes and how face recognition naturally varies as a function of participant age and goals. One limitation of the present study is that, due to the physical differences between young and older adult bodies, the face position could not be reversed to create two versions of each scene (i.e., controlling for the location of the young and older faces on the computer screen). However, we did ensure that the percentage of the screen occupied by young and older faces was equivalent across all scenes, and our pilot test revealed that body placement did not selectively attract participants' attention to one face age more than the other. A second limitation of the current study is that we did not examine the stability of individual differences in attentional allocation and the extent to which these differences are influenced by implicit attitudes towards young and older adults.

The novel method used in the current study provides a promising avenue for future research examining face recognition in a more ecologically valid manner. Future studies can utilize this method and examine attentional allocation and recognition for other relevant face categories, such as attractive versus unattractive faces. Furthermore, it is possible to examine the role of social context in face recognition by manipulating the social environment in which the faces appear. For example, older adult faces could be presented in a youthful setting (e.g., a carnival), indicating that the older adult is "young-old" rather than "old-old" (Neugarten & Hagestad, 1976) and therefore may be perceived as more versus less relatable to a young adult. Lastly, future studies should further examine the effect of task instruction. For example, in our task, we drew participants' attention to the faces in even the impressions condition because we wanted to ensure that participants at least briefly encoded each face. However, future studies should examine participants' recognition following passive viewing of the scenes or following instructions that systematically direct attention to other aspects of the scene and make the faces task-irrelevant (e.g., by asking participants to form an impression of the architecture).

In summary, the present study confirmed the existence of an own-age bias in young adults for attentional allocation during learning and subsequent recognition memory. Older adult participants in our sample looked longer and more frequently at young adult faces during learning but showed comparable recognition for young and older faces. For both age and instruction groups, there was no relationship between looking time and subsequent recognition. Our results have important implications for the way in which faces of different ages are processed in natural situations that contain numerous environmental stimuli that compete for attention. As the population of older adults continues to grow, it will become increasingly important to understand the way in which older adults perceive and are perceived by others in their daily social interactions and everyday life experiences.

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CHAPTER 5

Study 4: Normality Judgments and Discrimination for Young and Older Faces Among Young and Older Adults[9]

Adults are considered experts in face processing; however, their expertise is limited to the face categories with which they have the most experience—for example, faces of their own race (Rhodes, Hayward, & Winkler, 2006) and age (Anastasi & Rhodes 2005; Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008). A wealth of studies have investigated one insidious social phenomenon—inferior recognition of other-race compared to own-race faces (reviewed in Meissner & Brigham, 2001). Here we investigate the roots of another—reduced recognition of older adults' faces compared to those of young adults.

The majority of research investigating limitations in expertise has examined the other-race effect, the finding that own-race faces are recognized more accurately than other-race faces. Two potential explanations have been posed to account for this effect. According to the perceptual expertise hypothesis, reduced experience with other-race faces leads to their being processed less holistically (e.g., Michel, Caldara, & Rossion, 2006; Tanaka, Kiefer, & Bukach, 2004; but see Mondloch et al., 2010a) and to reduced sensitivity to differences among faces in the shape and spacing of facial features (e.g., Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010a). In contrast, the socio-cognitive hypothesis states that different social cognitions are elicited by own- and other-race faces; other-race faces are classified as out-group members and are thus processed at the categorical rather than the individual level (Hugenberg, Young, Bernstein, & Sacco,

[9] This chapter is based on the published article: Short, L. A., & Mondloch, C. J. (2013). Aging faces and aging perceivers: Young and older adults are less sensitive to deviations from normality in older than in young adult faces. *Perception, 42*, 795-812. doi: 10.1068/p7380

2010; Sporer, 2001). This tendency to focus on category membership leads to decreased motivation to attend to other-race faces (Rodin, 1987) and reduced encoding of the individuating features of other-race faces (Ge et al., 2009; Levin, 2000).

Although a large body of literature exists on the other-race effect, much less is known about a closely related phenomenon—the other-age effect. Several studies have found that own-age faces are recognized and processed more efficiently than other-age faces (Anastasi & Rhodes, 2006; Wright & Stroud, 2002). For example, young adults show a reduced inversion effect when recognizing child and newborn faces relative to adult faces (Kuefner et al., 2008) and decreased holistic processing when examining child faces relative to adult faces in a composite face task (de Heering & Rossion, 2008). Although the other-age effect is generally quite robust among young adults, there is inconsistent evidence among older adults and children (for a review, see Rhodes & Anastasi, 2012), with some studies showing that older adults and children exhibit enhanced recognition for own-age relative to other-age faces (Anastasi & Rhodes, 2005; Perfect & Harris, 2003) and other studies showing that they perform equally well with young adult and own-age faces (Fulton & Bartlett, 1991; He, Ebner, & Johnson, 2011; Wiese, Schweinberger, & Hansen, 2008).

Better recognition of adult versus child faces has been attributed to early experience. During infancy, young adult faces are typically the most frequently encountered in daily life (Rennels & Davis, 2008), a bias that may contribute to a recognition advantage for faces in this age range (Macchi Cassia, 2011). The importance of early experience is evident in a series of elegant studies demonstrating the impact of exposure to younger/older siblings. Young children who have infant siblings demonstrate enhanced recognition for infant faces relative to children who do not have younger siblings (Macchi Cassia, Kuefner, Picozzi, & Vescovo, 2009a), and 3-year-old children with older siblings (i.e., who received experience with child faces during infancy) are equally skilled in recognizing child and adult faces whereas children without older siblings are best at recognizing adult faces (Macchi Cassia, Pisacane, & Gava, 2012). Early and continuous exposure throughout development to young adult faces may set up the perceptual system in a way that is preferentially tuned to differences among young adult faces rather than faces of children or older adults.

There is some evidence that extensive experience in adulthood can mitigate or eliminate perceptual biases acquired early in life. For example, young adults working as preschool teachers are equally accurate in recognizing young adult and child faces (Harrison & Hole, 2009; Kuefner et al., 2008) and show comparable levels of holistic processing for adult and child faces (de Heering & Rossion, 2008). Furthermore, maternity ward nurses exhibit a smaller recognition advantage for young adult relative to infant faces than young adults who lack experience with infants (Macchi Cassia, Picozzi, Kuefner, & Casati, 2009b; but see Yovel et al., 2012). Although these findings suggest that the face processing system remains malleable throughout life, experience acquired in adulthood may not modulate the system to the same degree as experience acquired in infancy and childhood. For example, exposure to infant faces during adulthood improves recognition for infant faces most in individuals who had a younger sibling (i.e., who received abundant exposure to infant faces early in life) (Macchi Cassia et al., 2009a). Likewise, in terms of race effects, plasticity for other-race faces is limited after 9 years of age (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005); Korean children adopted into Caucasian families by 9 years of age recognize Caucasian faces more accurately than Asian faces as adults, plasticity that is not observed in Korean individuals who moved to France during adulthood. Thus experience with a new class of faces may exert greater influence on the perceptual system during childhood than adulthood.

One conceptualization of perceptual tuning is norm-based coding, a process by which individual faces are encoded relative to a face prototype that represents the average of all faces previously encountered (Valentine, 1991); "Bob", for example, is recognized because his nose is wider and his eyes are closer together than average. This prototype rests at the center of a multidimensional face space that is likely optimized for the dimensions of the face categories most frequently observed (Valentine & Endo, 1992). Norm-based coding influences the perception of attractiveness and normality, such that faces that are close to the prototype are rated as more attractive and normal looking than those that are distant (Rhodes & Tremewan, 1996). There is widespread agreement among adults regarding the attractiveness and normality of faces (e.g., Cross & Cross, 1971), and even infants look longer at faces that have previously been rated as attractive by adults—at least when the faces are those of young adults (Langlois et al., 1987).

Given the wealth of experience we have with young adult faces, it is likely that the dimensions of face space are optimized for young adult faces. As adults age, their faces change in both texture (e.g., wrinkles develop) and shape (e.g., redistribution of adipose tissue, lengthening of the ears and nose) (Burt & Perrett, 1995), a process that may increase distance from the prototype. The norm-based coding model predicts worse recognition and reduced sensitivity to variation in attractiveness/normality for faces from categories with which we have less experience because those faces are located quite distant from the prototype (i.e., the average face) and are tightly clustered in multidimensional face space (Valentine, 1991). Recent evidence suggests that adults may possess multiple face prototypes/norms that represent the different face categories (e.g., race, age) encountered in the environment (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008); however, the norm and underlying dimensions for some categories (e.g., other-race, other-age) appear to be less well refined, as reflected by poorer recognition and discrimination for face categories less frequently encountered (reviewed in Meissner & Brigham, 2001). In the current study, we directly tested the hypothesis that age-related changes in the faces of older adults may make a face space potentially optimized for young adult faces less effective for perceiving older adult faces and, more specifically, for judging normality. Thus, regardless of whether there is a single face prototype or multiple face prototypes for faces of different ages in face space, the dimensions of face space may be optimized for the face age category with which we have the most experience (e.g., young faces).

We used participants' normality judgments as a tool to examine individuals' sensitivity to the dimensions on which young and older adult faces vary. Participants viewed young (19 to 24 years) and older adult (71 to 79 years) face pairs; one member of each pair was undistorted and the other had features that were compressed towards the center of the face or expanded outward (as in a concave/convex mirror). Participants were asked to indicate which member of each pair was more normal to test the hypothesis that judgments of normality would be more accurate for young faces. We tested both young and older adults to determine whether abundant experience with older faces later in life increases sensitivity to deviations from the norm. Given that young adults have a wealth of experience with young adult faces and consistently show an own-age recognition bias (Macchi Cassia, 2011), we hypothesized that young adults would show an advantage for young faces in the normality judgment task. Evidence for an own-age bias in older adults is less consistent (e.g., Anastasi & Rhodes, 2005; Fulton & Bartlett, 1991), and thus we made no single prediction as to whether older adults would show an advantage for young versus older adult faces in the normality judgment task. If the perceptual system is set up during infancy and childhood based upon early experience (typically with young adult faces) and becomes relatively inflexible later in life, then older adults should show an advantage for young adult faces. However, if recent, extensive experience with one's age group is sufficient to alter the perceptual system and optimize face space for own-age faces, then older adults should show an advantage for older faces.

The normality judgment task required participants to rely on norm-based coding and to have an understanding of how faces deviate from a prototypical face. Nonetheless, two potential mechanisms could explain lower accuracy for older faces than young faces in the normality judgment task: deficits in norm-based coding or mere deficits in discriminating older adult faces. To determine the extent to which differential accuracy in normality judgments could be attributed to impaired discrimination of older adult faces rather than norm-based coding per se, we also tested participants on a discrimination task in which they viewed the same face pairs shown in the normality judgment task, which allowed us to directly compare performance across the two task types. In the discrimination task, participants were simply asked to indicate which member of each face pair was more expanded. We hypothesized that any advantage for young adult faces in the normality task would be reduced or eliminated in the discrimination task; the discrimination task did not require perceptual expertise, a hypothesis we directly tested in Experiment 2, and thus served largely as a control task to ensure that participants were capable of telling the two faces in each pair apart.

Experiment 1

Method

Participants. Sixteen Caucasian undergraduate students from Brock University (12 female; M = 19.81 years, age range = 18-25) and 16 Caucasian senior citizens living in independent housing in the Niagara region of Ontario (11 female; M = 71.69 years, age range = 63-87) participated in this experiment. Senior citizen participants were all in good health and had at least 20/30 vision when tested from a distance of 8 feet; no older adult participant reported farsightedness or difficulty in viewing items shown on a computer screen. Undergraduate participants received research credit or a small honorarium and senior citizens received a gift card for their participation in the study. Participants completed a questionnaire assessing their weekly face-to-face contact with both young and older adults (see Appendix 4). Undergraduate participants reported an average of 58.27 hours per week interacting with young adults and 11.53 hours per week interacting with older adults. In contrast, senior citizen participants reported an average of 4.38 hours per week interacting with young adults and 27.10 hours per week interacting with older adults.

Materials. Both practice and test stimuli consisted of colored photographs of Caucasian young (age range = 19-24) and older adult faces (age range = 71-79). All stimuli were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) and resized such that the distance from hairline to chin was approximately

450 pixels. Twelve young adult (6 female) and 12 older adult (6 female) faces were used as test stimuli. We used the spherize tool in Adobe Photoshop Version 8.0 to expand and compress the internal features of each face (see Figure 5.1); using this technique, we created six new versions of each identity (-30%, -20%, -10%, +10%, +20%, +30%). For each identity, we then created six face pairs such that each level of distortion was paired with its undistorted same-identity counterpart (e.g., an undistorted face was paired with a +10% face of the same identity). The left/right positioning of the undistorted member of each pair was counterbalanced such that for each age of face and each distortion level (e.g., undistorted paired with -10%), the undistorted face appeared on the left for half of the trials. The same identities and pairings were used in both the normality judgment task and the expanded discrimination task.

An additional four identities (two older adult) were used as practice stimuli in both tasks. Each practice trial (n = 4) consisted of a ±40% face paired with an undistorted face of the same identity. The distorted face appeared on the right on two of these trials. All stimuli were presented and responses were recorded using SuperLab 4.5 software.

Procedure. The procedure received clearance from the Research Ethics Board at Brock University, and participants gave written informed consent prior to their participation. Upon arrival to the lab, participants were seated approximately 60 cm in front of a 23-inch computer screen. The order in which participants completed the two tasks was counterbalanced such that half of the participants completed the normality judgment task followed by the expanded discrimination task, and the other half completed the two tasks in the reverse order.

In the normality judgment task, participants were told that they would be shown a series of face pairs and that they were to select the more normal-looking face in each pair. Prior to testing, participants were shown four practice trials to ensure that they understood task instructions. Practice trials consisted of an undistorted face paired with a ±40% face of the same identity, and each pair was shown for 3000 ms. Participants were asked to verbally indicate whether the face on the right or on the left appeared more normal looking; verbal responses were used because pilot testing revealed that senior citizen participants preferred giving verbal responses rather than using a joystick because it made the testing session more interactive for them. Following the practice trials, participants were shown 144 face pairs (12 identities across 6 levels of distortion for each of the two age categories). The order in which the pairs were shown was fully randomized. Each trial consisted of a 500-ms fixation cross followed by a face pair that appeared for 3000 ms. The face pair was then replaced by a screen prompting participants to select the more normal-looking face in each pair. Participants verbally indicated "left" or "right" and the experimenter entered their response in the computer before advancing to the next trial.

The procedure of the expanded discrimination task was identical to that of the normality judgment task, except that participants were asked to select the more expanded face in each pair rather than identify the more normal-looking face. An expanded face was defined as having larger, more stretched out features than its same-identity counterpart.

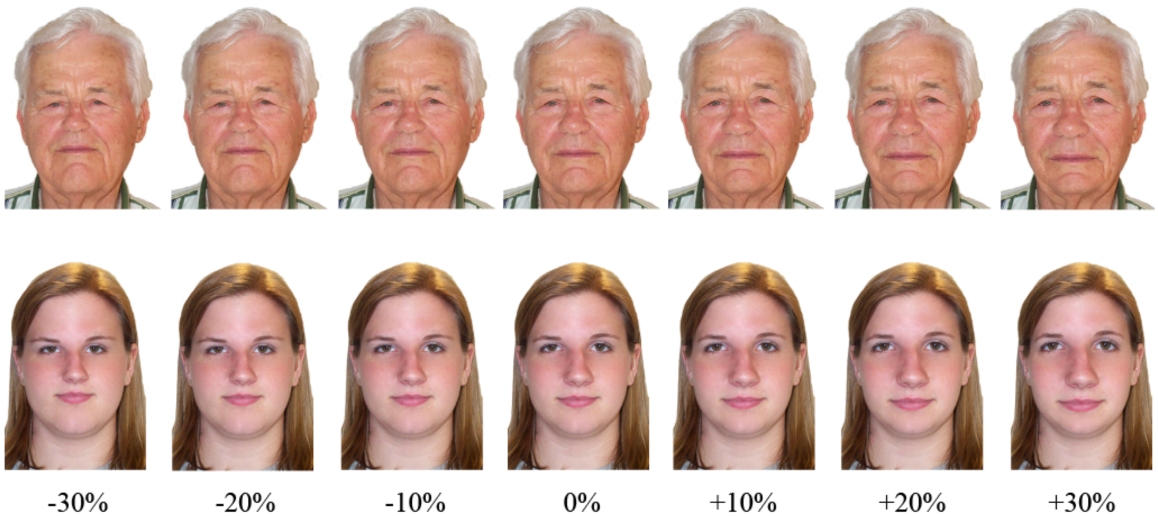

Figure 5.1. Sample distortion continua for an older adult identity and young adult identity. Each face pair consisted of an undistorted face paired with an expanded or compressed version of the same identity.

Results

To simplify our analysis, we collapsed across expanded and compressed trials within each distortion level[10]. For the normality judgment task, we calculated the proportion of trials on which each participant selected the undistorted face in a face pair as being more normal than the distorted face; we did so for each distortion level within each of the two face age categories. For the expanded discrimination task, we calculated the proportion of trials on which each participant selected the more expanded face in a face pair as being more stretched out than its same-identity counterpart.

Preliminary analyses indicated that task order did not have a significant effect on accuracy nor did it interact with any other variables, all *p*s > .10; thus we did not include order in any subsequent analyses. We conducted a 2 (task: normality, discrimination) x 2 (face age: young adult, older adult) x 3 (distortion: 10%, 20%, 30%) x 2 (participant age: young adult, older adult) mixed ANOVA to examine whether face age differentially influenced young and older adults' accuracy across distortion levels in the two types of task. As shown in Figure 5.2, young adults performed with greater accuracy than older adults in both tasks; however, both age groups were more accurate with young faces than older faces in the normality task but not in the discrimination task. There was a main effect of participant age, $F(1, 30) = 18.02$, $p < .001$, $\eta_p^2 = .38$, such that young adults' accuracy ($M = .82$, $SE = .02$) was higher than older adults' ($M = .68$, $SE = .02$). There was also a main effect of task, $F(1, 30) = 5.58$, $p = .03$, $\eta_p^2 = .16$, and a main effect of face age, $F(1, 30) = 15.46$, $p < .001$, $\eta_p^2 = .34$. Accuracy was higher in the discrimination task ($M = .78$, $SE = .03$) than in the normality task ($M = .72$, $SE = .02$), and for young adult

[10] An examination of accuracy at the level of specific face identities indicated that errors were randomly distributed across identities, with the difference in accuracy between expanded and compressed distortions not differing between young and older faces at each level of distortion, all *p*s > .30.

faces (*M* = .77, *SE* = .02) than older adult faces (*M* = .73, *SE* = .02). Lastly, there was a main effect of distortion level, $F(2, 60) = 150.38$, $p < .001$, $\eta_p^2 = .83$, such that accuracy increased as distortion level increased.

Both young and older adults were more accurate when tested with young faces compared to older faces—but only when judging normality. This task by face age interaction, $F(1, 30) = 23.63$, $p < .001$, $\eta_p^2 = .44$, was significant. The participant age by distortion, $F(2, 60) = 5.07$, $p = .01$, $\eta_p^2 = .14$, and the task by distortion, $F(2, 60) = 10.16$, $p < .001$, $\eta_p^2 = .25$, interactions were also significant. Most notably, there was a three-way interaction of task by face age by distortion, $F(2, 60) = 6.64$, $p = .002$, $\eta_p^2 = .18$. To examine the nature of the three-way interaction, we conducted a 2 (task) by 2 (face age) repeated-measures ANOVA for each distortion level to determine whether the differences in accuracy between young and older adult faces varied across task type at each level of task difficulty (see Figure 5.2). Because age of participant did not influence this interaction ($p > .10$), we collapsed across participant age in all subsequent analyses.

For 10% face pairs, there was a main effect of task, $F(1, 31) = 11.35$, $p = .002$, $\eta_p^2 = .27$, such that accuracy was higher on the discrimination task (*M* = .70, *SE* = .03) than the normality task (*M* = .61, *SE* = .02). No other effects were significant, all *p*s > .10. For 20% face pairs, there was a main effect of task, $F(1, 31) = 9.40$, $p = .004$, $\eta_p^2 = .23$, a main effect of face age, $F(1, 31) = 10.42$, $p = .003$, $\eta_p^2 = .25$, and a significant two-way interaction, $F(1, 31) = 21.58$, $p < .001$, $\eta_p^2 = .41$. Paired-samples t-tests[11] revealed that accuracy was higher for young adult faces (*M* = .76, *SE* = .02) than for older adult faces (*M* = .66, *SE* = .02), $t(31) = -4.96$, $p < .001$, Cohen’s $d = .74$, in the normality task, but

[11] All t-tests were two-tailed unless otherwise noted.

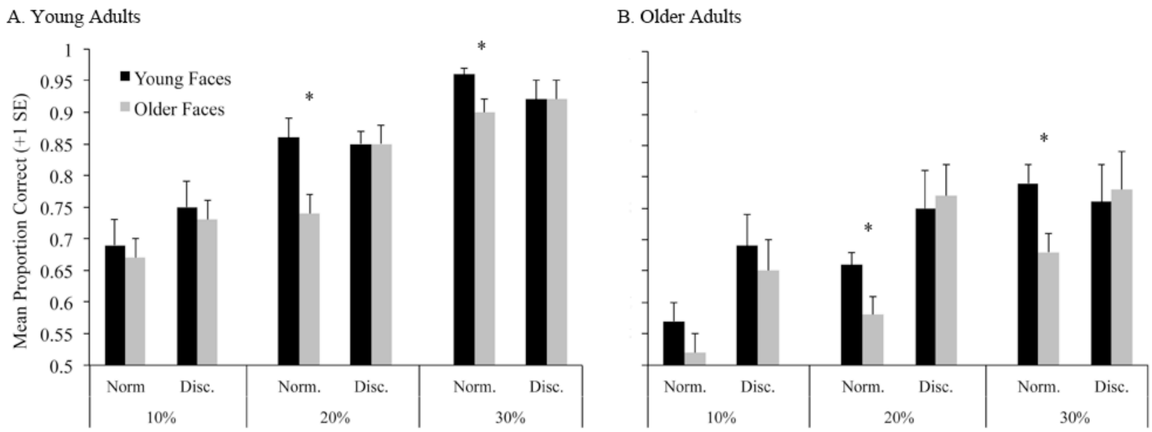

Figure 5.2. Mean proportion correct (+1 SE) for both the normality and discrimination tasks for young and older adult faces at each level of distortion for young (A) and older adult (B) participants in Experiment 1. Asterisk indicates that $p < .05$.

not in the discrimination task (M = .80, SE = .03 and M = .81, SE = .03 for young and older adult faces, respectively, $t(31) = .39$, $p = .70$, Cohen's $d = .06$). For 30% face pairs, there was a main effect of face age, $F(1, 31) = 11.51$, $p = .002$, $\eta_p^2 = .27$, and a significant task by face age interaction, $F(1, 31) = 19.45$, $p < .001$, $\eta_p^2 = .39$. Paired-samples t-tests revealed that accuracy was higher for young adult faces (M = .88, SE = .02) than for older adult faces (M = .79, SE = .03), $t(31) = -4.93$, $p < .001$, Cohen's $d = .68$, in the normality task, but not in the discrimination task (M = .84, SE = .04 and M = .85, SE = .03 for young and older adult faces, respectively, $t(31) = .46$, $p = .65$, Cohen's $d = .05$).

Although participant age did not influence the task by face age by distortion interaction, we elected to separately examine young and older adults' accuracy in the two tasks to ensure that both age groups showed the same pattern of performance at the 20% and 30% distortion levels. As shown in Figure 5.2, for young adults, accuracy was higher for young than older faces in the normality task at both 20%, $t(15) = -4.31$, $p = .001$, Cohen's $d = 1.14$, and 30% distortions, $t(15) = -4.21$, $p = .001$, Cohen's $d = .95$. In contrast, there was no difference in accuracy for young and older faces in the discrimination task at both 20%, $t(15) = -.23$, $p = .82$, Cohen's $d = .09$, and 30% distortions, $t(15) = -.19$, $p = .85$, Cohen's $d = 0$. For older adults, accuracy was higher for young than older faces in the normality task at 20%, $t(15) = -2.76$, $p = .02$, Cohen's d = .84, and 30% distortions, $t(15) = -3.64$, $p = .002$, Cohen's $d = .95$. There was no difference in accuracy for young and older faces in the discrimination task at both 20%, $t(15) = .73$, $p = .48$, Cohen's $d = 0$, and 30% distortions, $t(15) = .62$, $p = .54$, Cohen's d = .08.

Discussion

Older adults were less accurate than young adults on both tasks, which supports previous work suggesting that face processing abilities decline with age (e.g., Crook & Larrabee, 1992). For example, performance on the Cambridge Face Memory Test—a test that requires participants to learn multiple faces and then recognize those same faces under different viewing angles and lighting conditions, begins to steadily decline after 50 years of age (Bowles et al., 2009). Although older adults made more errors than young adults in our task, both age groups showed the same pattern of results: despite no difference in the accuracy with which participants were able to discriminate young and older adult faces, judgments of normality were more accurate for young adult faces. Collectively, these results suggest that 1) the perceptual system is preferentially tuned towards the dimensions of young adult faces, perhaps as a result of early experience and 2) abundant experience with older faces later in life does not reverse this perceptual tuning.

The discrepant pattern of results between the normality judgment task and the discrimination task suggests that the deficit for older adult faces is related to decreased expertise in processing the dimensions along which older faces vary, which may reflect reduced efficiency in the use of norm-based coding. Although norm-based coding may facilitate identity discrimination (Armann, Jeffery, Calder, & Rhodes, 2011; but see Ng, Boynton, & Fine, 2008), the normality judgment and discrimination tasks likely tapped into different perceptual processes, which may help explain the different pattern of results between the two tasks. The identification of a normal-looking face requires reliance on perceptual expertise, such as a well-defined norm(s) and sensitivity to both featural and configural facial information. In contrast, the identification of the expanded face in a pair does not require norm-based coding; instead, participants can simply use a feature-based approach and make their judgments based on the size of a single facial feature (e.g., the face with the largest nose). This process does not require expertise whereas high accuracy in the normality judgment task requires fine-tuned sensitivity to multiple facial dimensions. To illustrate this idea, imagine that participants are shown pairs of coffee mugs. In each pair, one coffee mug is undistorted while the other mug is expanded or compressed. Participants could easily identify the expanded coffee mug by focusing on which mug has the largest handle; however, it would be significantly more difficult for participants to identify which mug is more normal-looking unless they have had extensive experience in examining mugs of different shapes and sizes. In this same way, participants in our experiment may be fully capable of identifying expanded young and older faces but may lack the expertise and sensitivity required to gauge the normality of older relative to young faces.

To test the hypothesis that the normality judgment task and the expanded discrimination task tapped into different perceptual processes, we conducted a second experiment in which half of the participants judged the normality and expandedness of upright faces and half completed these same two tasks with inverted faces. Only young adults participated. The primary hypothesis of Experiment 2 was that inversion would differentially affect performance between the two task types such that inversion would reduce the accuracy of normality judgments to a greater extent than the accuracy of discrimination.

Experiment 2

The purposes of Experiment 2 were two-fold. Our primary goal was to investigate whether inversion would affect the accuracy of normality judgments to a greater extent than discrimination accuracy. Inversion impairs recognition of faces more than recognition of most other objects (Yin, 1969) and a large inversion effect is considered a marker of perceptual expertise (Kuefner et al., 2008; reviewed in Maurer, Le Grand, & Mondloch, 2002). Inversion disrupts two markers of expert processing: holistic perception (Hole, 1994; Mondloch & Maurer, 2008; Tanaka & Farah, 1993) and sensitivity to feature spacing (Freire, Lee, & Symons, 2000; Mondloch, Le Grand, & Maurer, 2002); sensitivity to feature shape is less impaired (Mondloch, Robbins, & Maurer, 2010b; Rhodes et al., 2006), perhaps because inverted faces are processed by shape-generic rather than face-specific mechanisms (Susilo, McKone, & Edwards, 2010). Thus if performance on the normality judgment task reflects perceptual expertise to a greater extent than performance on the discrimination task, then 1) inversion should impair performance on the normality judgment task to a greater extent than performance on the discrimination task; and 2) it should reduce or eliminate the advantage for young adult faces on the normality judgment task.

Our secondary goal was to replicate the original finding with upright faces using a different set of young and older adult identities and without providing our participants with an explicit definition of an “expanded” face. It is possible that due to the limited number of identities used in Experiment 1, idiosyncratic differences in the original identities may have led to the difference in accuracy for young and older adult faces in the normality task (e.g., the majority of the older adult identities could have had abnormally large noses and thus the compressed distortion could have moved the faces closer to the prototype). By increasing the number of identities used across the two experiments, we can ensure that idiosyncratic differences in the stimuli do not account for our pattern of results. Furthermore, in Experiment 1, participants were provided with a verbal description of an expanded face and it is possible that this description may have decreased the difficulty of the discrimination task relative to the normality task. Thus in Experiment 2, we did not provide participants with this formal definition and instead allowed them to form their own definition of expandedness. We hypothesized that despite these changes to the task, participants would show an advantage for upright young adult faces in the normality task but not in the discrimination task, which would be consistent with the results of Experiment 1.

Method

Participants. Thirty-two Caucasian undergraduate students from Brock University (30 female; *M* = 19.31 years, age range = 18-27) participated in this experiment. All participants received research credit or a small honorarium for their participation in the study. Participants completed a questionnaire assessing their weekly face-to-face contact with both young and older adults. Participants reported an average of 55.94 hours per week interacting with young adults and 7.11 hours per week interacting with older adults.

Materials. Both practice and test stimuli consisted of colored photographs of Caucasian young (age range = 18-26) and older adult faces (age range = 72-80). Stimuli were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) or from photographs taken in our lab and were resized such that the distance from hairline to chin was approximately 450 pixels. Twelve young adult (6 female) and 12 older adult (6 female) faces were used as test stimuli; these identities differed from those used in Experiment 1. We used the spherize tool in Adobe Photoshop Version 8.0 to expand and compress the internal features of each face; using this technique, we created four new versions of each identity (-30%, -20%, +20%, +30%). We did not include ±10% distortions because Experiment 1 demonstrated that there were no differences in accuracy between young and older faces at ±10% distortions for either the normality judgment or the discrimination task. For each identity, we then created four face pairs such that each level of distortion was paired with its undistorted same-identity counterpart (e.g., an undistorted face was paired with a +20% face of the same identity). The left/right positioning of the undistorted member of each pair was counterbalanced such that for each age of face and each distortion level (e.g., undistorted paired with -30%), the undistorted face appeared on the left for half of the trials. To create the inverted pairs, each upright face pair was simply inverted using Adobe Photoshop. The same identities and pairings were used in both the normality judgment task and the expanded discrimination task.

An additional eight identities (four older adult) were used as practice stimuli. Four practice trials (two older adult) consisted of a ±60% face paired with an undistorted face of the same identity. The distorted face appeared on the right on two of these trials. An additional four practice trials (two older adult) consisted of a ±30% face paired with an undistorted face of the same identity. The distorted face appeared on the right on two of these trials. Both upright and inverted versions were created for each of the practice face pairs. The same practice trials were used in the normality and discrimination tasks.

Similar to Experiment 1, all stimuli were presented and responses were recorded using SuperLab 4.5 software.

Procedure. The procedure received clearance from the Research Ethics Board at Brock University, and participants gave written informed consent prior to their participation. Upon arrival to the lab, participants were seated approximately 60 cm in front of a 23-inch computer screen. For half of the participants, all face pairs in both the normality judgment task and the expanded discrimination task were shown in an upright orientation, and for the other half of participants, all face pairs were shown in an inverted orientation. In both orientation groups, the order in which participants completed the two tasks was counterbalanced such that half of the participants completed the normality judgment task followed by the expanded discrimination task, and the other half completed the two tasks in the reverse order.

Prior to beginning the experiment, participants were told that they would be shown pictures of faces, some of which might appear unusual, as though the person were looking at a concave or convex mirror at a funhouse. They were then shown an image of a person's reflection in a concave mirror as well as an image of a person's reflection in a convex mirror.

Following this introduction to the distortions used in the experiment, participants completed the first of the two tasks in the study. In the normality judgment task, participants were told that they would be shown a series of face pairs and that they were to select the more normal-looking face in each pair. Prior to testing, participants completed a series of practice trials to ensure that they understood task instructions. The first four practice trials consisted of an undistorted face paired with a ±60% face of the same identity, and the second four practice trials consisted of an undistorted face paired with a ±30% face of the same identity. Each face pair was shown for 3000 ms, and participants were asked to verbally indicate whether the face on the right or on the left appeared more normal looking. For participants in the upright condition, all face pairs in the practice trials were shown in an upright orientation. In contrast, participants in the inverted condition first completed the same eight upright trials as those in the upright condition and then completed these eight trials in an inverted orientation. This additional practice was given to those in the inverted condition to ensure that they understood the facial manipulations before the task was made more difficult by inverting the faces. Following the practice trials, participants were shown 96 face pairs (12 identities across 4 levels of distortion for each of the two age categories). The order in which the pairs were shown was fully randomized. Each trial consisted of a 500-ms fixation cross followed by a face pair that appeared for 3000 ms. The face pair was then replaced by a screen prompting participants to select the more normal-looking face in each pair. Participants indicated via joystick whether the face on the left or right was more normal looking, and they had an unlimited amount of time to respond. Once participants indicated their response, the next trial began.

The procedure of the expanded discrimination task was identical to that of the normality judgment task, except that participants were asked to select the more expanded face in each pair rather than identify the more normal-looking face. Rather than providing participants with a verbal description of an expanded face, participants were told that an expanded face was similar to the image that was previously shown to them of a person's reflection in a convex mirror.

Results

Similar to Experiment 1, to simplify our analysis, we collapsed across expanded and compressed trials within each distortion level. For the normality judgment task, we calculated the proportion of trials on which each participant selected the undistorted face in a face pair as being more normal than the distorted face; we did so for each distortion level within each of the two face age categories. For the expanded discrimination task, we calculated the proportion of trials on which each participant selected the more expanded face in a face pair as being more stretched out than its same-identity counterpart. Preliminary analyses indicated that task order did not have a significant effect on accuracy nor did it interact with any other variables, all *p*s > .10; thus we did not include order in any subsequent analyses.

Our primary goal was to examine whether inversion affected the accuracy of normality judgments to a greater extent than the accuracy of discrimination. We conducted a 2 (task: normality, discrimination) x 2 (face age: young adult, older adult) x 2 (distortion: 20%, 30%) x 2 (orientation: upright, inverted) mixed ANOVA with accuracy as the dependent variable (see Figure 5.3). There was a main effect of task, $F(1, 30) = 41.10$, $p < .001$, $\eta_p^2 = .58$, such that accuracy was higher in the discrimination task ($M = .90$, $SE = .02$) than in the normality task ($M = .78$, $SE = .01$). There was also a main effect of face age, $F(1, 30) = 10.31$, $p = .003$, $\eta_p^2 = .26$, and a main effect of distortion, $F(1, 30) = 76.82$, $p < .001$, $\eta_p^2 = .72$. Accuracy was higher for young adult faces ($M = .85$, $SE = .02$) than older adult faces ($M = .82$, $SE = .02$), and for 30% distortions ($M = .88$, $SE = .02$) than 20% distortions ($M = .79$, $SE = .02$). Lastly, there was a main effect of orientation, $F(1, 30) = 7.72$, $p = .009$, $\eta_p^2 = .21$, such that accuracy was higher for those

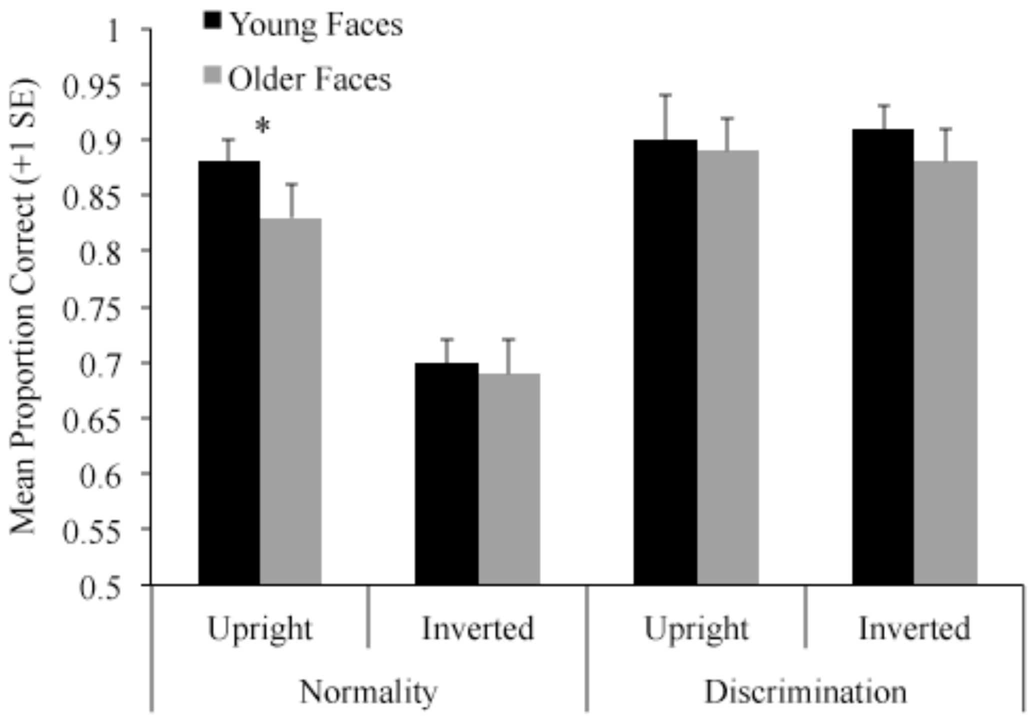

Figure 5.3. Mean proportion correct (+1 SE) for both the normality and discrimination tasks for young and older adult faces in the upright and inverted orientations (Experiment 2). Asterisk indicates that $p < .05$.

in the upright condition (*M* = .88, *SE* = .02) than for those in the inverted condition (*M* = .80, *SE* = .02).

Most notably, the predicted task by orientation interaction was significant, $F(1, 30) = 18.07$, $p < .001$, $\eta_p^2 = .38$, consistent with our hypothesis that inversion would impair performance on the normality judgment task more than performance on the discrimination task. In the discrimination task, there was no difference in accuracy between participants in the upright condition (*M* = .90, *SE* = .03) and participants in the inverted condition (*M* = .90, *SE* = .02), $t(30) = -.07$, $p = .95$, Cohen's $d < .001$. However, in the normality judgment task, accuracy was higher for participants in the upright condition (*M* = .85, *SE* = .02) than for participants in the inverted condition (*M* = .70, *SE* = .02), $t(30) = 5.54$, $p < .001$, Cohen's $d = 1.76$. There was also a significant task by distortion interaction, $F(1, 30) = 8.89$, $p = .006$, $\eta_p^2 = .23$, and a marginally significant three-way interaction of task by distortion by orientation, $F(1, 30) = 3.57$, $p = .07$, $\eta_p^2 = .11$. No other effects were significant, all *p*s > .10; most notably none of the two- and three-way interactions with face age were significant, *p*s > .32 and *p*s > .14 respectively.

The significant task by orientation interaction and our a priori hypotheses based on Experiment 1 compelled us to conduct separate 2 (face age: young adult, older adult) x 2 (orientation: upright, inverted) mixed ANOVAs for each task (normality and discrimination). Our goal here was to examine whether inversion reduced or eliminated the advantage for young adult faces in the normality task. For the normality task, there was a main effect of face age, $F(1, 30) = 7.06$, $p = .01$, $\eta_p^2 = .19$, such that accuracy was higher for young adult faces (*M* = .79, *SE* = .01) than for older adult faces (*M* = .76, *SE* = .02). There was also a main effect of orientation, $F(1, 30) = 30.68$, $p < .001$, $\eta_p^2 = .51$;

accuracy was higher in the upright (M = .85, SE = .02) than in the inverted condition (M = .70, SE = .02). There was no significant face age by orientation interaction, $F(1, 30) = 1.89$, $p = .18$, $\eta_p^2 = .06$; however, based on our a priori hypothesis that the young adult face advantage would be present in only the upright condition in the normality task, we compared accuracy for young versus older adult faces in both orientation conditions. Paired-sample t-tests revealed that accuracy was higher for young (M = .88, SE = .02) than older faces (M = .83, SE = .02) in the upright condition, $t(15) = -3.05$, $p = .008$, Cohen's d = .53. However, there was no difference in accuracy for young (M = .70, SE = .02) and older faces (M = .69, SE = .02) in the inverted condition, $t(15) = -.85$, $p = .41$, Cohen's d = .11.

For the discrimination task, there was no main effect of either face age, $F(1, 30) = 3.18$, $p = .09$, $\eta_p^2 = .10$, or orientation, $F(1, 30) = .01$, $p = .95$, $\eta_p^2 < .001$. Furthermore, there was no face age by orientation interaction, $F(1, 30) = .51$, $p = .48$, $\eta_p^2 = .02$. In both orientation conditions, there was no difference in accuracy for young and older faces, ps > .14 (see Figure 5.3).

Discussion

The key finding of Experiment 2 was that inversion differentially affected performance on the normality judgment and the discrimination tasks. There was no difference in accuracy between participants in the upright and inverted conditions in the discrimination task, but accuracy was higher for participants in the upright condition than in the inverted condition in the normality judgment task. These results suggest that the two tasks tap into different perceptual processes; performance in the normality judgment task reflects perceptual expertise and requires fine-tuned sensitivity to multiple dimensions of the face (e.g., distance between the eyes) whereas the discrimination task requires sensitivity only to featural information and performance is not impaired by inversion. This interpretation is consistent with inversion having another important effect: In the normality task, inversion eliminated the young adult face advantage seen in the upright condition; greater expertise for young faces is limited to their canonical upright orientation.

The results of the upright condition of Experiment 2 paralleled the results of Experiment 1 and support our conclusion that despite being able to discriminate young and older adult faces with comparable accuracy, adults show greater sensitivity to the dimensions along which young faces vary compared to older faces. In the normality task, there was no significant face age by orientation interaction; however, planned t-tests showed that judgments of normality were more accurate for young adult faces than older adult faces in the upright but not the inverted condition. In the discrimination task, there was no difference in accuracy for young and older faces in both orientation conditions. This replication indicates that the findings from Experiment 1 were not unique to the 24 identities used in the first experiment and that the verbal description that we provided for an expanded face in Experiment 1 did not bias our results by making the discrimination task easier than the normality judgment task. In Experiment 2, participants were not given a verbal description of “expandedness” and instead were shown only the pictures of a person looking in a convex and a concave mirror before they completed both tasks. Thus in Experiment 2 participants formed their own definition of “expandedness”, yet the results were comparable to those of Experiment 1.

General Discussion

Collectively, our results demonstrate evidence for a young adult face advantage in judgments of normality but not discrimination. This advantage for young adult faces was absent when faces were shown in an inverted orientation, which suggests that greater expertise for young relative to older faces may underlie this effect. Enhanced sensitivity to the dimensions along which young relative to older adult faces vary may be the product of the early and continuous experience we receive with young faces (Macchi Cassia, 2011). Our finding of a comparable advantage for young adult faces among older adults suggests that abundant experience with older faces later in life does not reverse this perceptual tuning.

It is well established that perceptual narrowing begins during infancy. By 6 to 9 months of age infants discriminate own-species and own-race faces more accurately than monkey faces and other-race human faces (Kelly et al., 2007; Pascalis, de Haan, & Nelson, 2002), although this narrowing can be prevented by experience (Pascalis et al., 2005; see also Bar-Haim, Ziv, Lamy, & Hodes, 2006). Likewise, by 3 years of age children recognize young adult faces more accurately than child faces (Macchi Cassia et al., 2012), perhaps because young adult faces are typically the most frequently encountered during infancy (Rennels & Davis, 2008). This narrowing can also be prevented by exposure to young siblings (Macchi Cassia et al., 2009a; Macchi Cassia et al., 2012). Given the extent to which perceptual narrowing occurs for the most frequently encountered face categories in infancy and childhood, it is possible that early experience with young adult faces enhances sensitivity to the dimensions along which young adult faces vary relative to the dimensions along which older adult faces vary. According to the norm-based coding model (Valentine, 1991), individual faces differ on a variety of dimensions (e.g., distance between the eyes), and each dimension is represented as a unique vector in a multidimensional face space. Our results suggest that face space is optimized for young adult faces and that sensitivity to the dimensions that code for faces that belong to other age categories (notably older adult faces) is less well refined.

Our finding that even older adults showed reduced accuracy in gauging the normality of older adult faces indicates that abundant experience with older faces later in life does not enhance sensitivity to deviations from the average in older adult faces. Just as the other-race effect can be reversed during childhood but not adulthood (Sangrigoli et al., 2005), the perceptual system may become specialized for young adult faces early in life and be incapable of acquiring comparable sensitivity to other-age faces later in adulthood. This interpretation contrasts with the recent finding that prolonged experience with elderly individuals equates discrimination accuracy for young and older faces in a two-alternative forced-choice match-to-sample task (Proietti, Pisacane, & Macchi Cassia, 2013) and with studies showing evidence that extensive experience with child (Hills, 2012; Hills & Lewis, 2011) or older adult faces (Anastasi & Rhodes, 2006) can mitigate or eliminate the recognition advantage for young adult faces. For example, in a recent meta-analysis, Rhodes and Anastasi (2012) report evidence for an own-age recognition bias in older adults. Furthermore, senior citizens who report greater daily life contact with older adults than young adults show an own-age bias whereas senior citizens who report comparable daily contact with young and older adults do not (Wiese, Komes, & Schweinberger, 2012), a pattern of results which suggests that significant meaningful exposure to older adults is sufficient to reverse the young adult recognition advantage that may have been acquired early in life. Nonetheless, evidence for an own-age bias in older adults is inconsistent and not found across all studies (Anastasi & Rhodes, 2005; Fulton & Bartlett, 1991; Rhodes & Anastasi, 2012).

Although the results of some studies suggest that face space maintains its flexibility throughout life, it is important to note that the aforementioned studies investigated recognition for own- and other-age faces whereas our study directly examined sensitivity to deviations from the norm and did not have a memory component. In our experiment, participants showed comparable accuracy in discriminating young and older face pairs because they could simply rely on a shape-generic feature-based approach and make their judgments based on the size of a single facial feature. Likewise, adults who have ample experience with elderly individuals may become more sensitive to feature differences among older faces and show enhanced recognition accuracy for older faces relative to inexperienced adults without a corresponding improvement in norm-based coding and other markers of perceptual expertise (e.g., holistic processing, sensitivity to feature spacing).

One marker of expertise is sensitivity to differences among faces in the spacing of features, a sensitivity that is greater for own-race faces than other-race faces (Mondloch et al., 2010a), houses (Robbins, Shergill, Maurer, & Lewis, 2011), and monkey faces (Mondloch, Maurer, & Ahola, 2006) and is impaired significantly by inversion (Mondloch et al., 2002; reviewed in Maurer et al., 2002). Future studies could examine the hypothesis that extensive experience with older faces improves accuracy in detecting featural changes to a greater extent than accuracy in detecting spacing changes in older faces by manipulating the featural (e.g., changing the shape of the eyes) or spacing (e.g., moving the eyes closer together) information in a set of young and older adult faces and examining performance in a same/different task (see Mondloch et al., 2010a). Older adults and young adults who have extensive experience with elderly individuals may show comparable accuracy for young and older faces in the featural condition; however, accuracy for young faces may be higher than that for older faces in the spacing condition despite abundant experience with older adult faces.

According to this hypothesis, experience with older adult faces may increase accuracy on a recognition task without influencing how older adult faces are represented (i.e., without increasing sensitivity to deviations from a prototypical face). Identity aftereffects provide an additional tool with which to examine whether recognition of older adult faces depends on norm-based coding. Past research (e.g., Rhodes & Jeffery, 2006) has repeatedly shown that young adult face identities are coded relative to a norm, but no study has examined whether older adult identities are coded in a similar manner. Furthermore, identity aftereffects for young adult faces of different categories indicate that face identity is coded relative to sex- (Rhodes et al., 2011) and race-specific (Armann et al., 2011) norms; thus it is possible that face identity is also coded relative to age-specific norms. To bridge the gap between recognition tasks in which older adults often show an own-age advantage (see above) and our finding of a young face advantage for normality judgments, a future study should examine whether the identity of older adult faces is coded relative to an age-generic (applied to all adult faces but resembling a young adult face) or an age-specific (older face) norm.

The other-age effect is frequently considered analogous to the other-race effect, as both effects are considered examples of the same underlying phenomenon (e.g., Wiese et al., 2012). Two potential explanations have been posed to account for the other-race effect, and by extension, the other-age effect. The perceptual expertise account emphasizes the importance of experience in shaping the face processing system; exposure to a given face category early in life leads to enhanced sensitivity to featural and spacing differences among faces from this category and to a well defined prototype (e.g., Hayward et al., 2008; Mondloch et al., 2010a). In contrast, the socio-cognitive account argues that initial in- and out-group biases lead to different processing strategies during the encoding of faces from two categories. Faces classified as belong to one's in-group are processed at the highly specific individual level whereas faces classified as out-group members are processed at the more superficial categorical level (Sporer, 2001). Our results support the perceptual expertise account and suggest that the perceptual processing system may be optimized for the category of face with which we have the most experience (i.e., young adult faces). Our results are inconsistent with the socio-cognitive model because in-group biases cannot account for our findings. Despite belonging to the older adult population, the senior citizens in our study showed enhanced accuracy in detecting normality in young adult faces relative to faces of their own age. Thus merely categorizing older adults as in-group members does not eliminate the effect of early perceptual tuning. We acknowledge, however, that motivational influences may have contributed to the increased accuracy for young adult faces in that both young and older adults have been shown to ascribe more positive attitudes to young versus older adults (He et al., 2011).

Despite the commonalities between the other-age effect and the other-race effect, one key difference between the two effects is that race remains consistent throughout the lifespan whereas age does not. Older adults represent a unique population because they have belonged to all ages throughout the lifespan; they have gained experience with numerous face ages and have belonged to each of the different age-related social categories throughout life. Thus by studying older adults it is possible to examine the cumulative effects of experience with different face ages throughout life as well as the specific effects of recent exposure to and social identification with older adults. It is not possible to examine such effects with regard to race, as one's race never changes. Furthermore, older adult faces are unique as a face category because these faces (i.e., these specific identities) were likely distributed around and close to the young adult prototype earlier in development but gradually acquired novel dimensions and moved systematically away from that prototype as a function of the physical and structural changes that accompany aging. This is in contrast to other-race faces, which remain consistent and do not gradually acquire the dimensions of own-race faces.

Past research has demonstrated that adults rely on dissociable face prototypes that represent the different face categories encountered in the environment. Such results stem from adaptation studies that have yielded evidence for category-contingent opposing aftereffects. Following repetitive exposure to two face categories that are distorted in opposite directions (e.g., expanded Chinese faces and compressed Caucasian faces), adults' judgments of normality and attractiveness shift in opposite directions, demonstrating that the norms for two face categories are concurrently moving in opposition to one another (Jaquet et al., 2008). Such effects have been found for faces that differ according to race (Jaquet et al., 2008; Little et al., 2008), sex (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005), and orientation (Rhodes et al., 2004).

Although one study has found evidence for dissociable norms for adult and infant faces (Little et al., 2008), no study to date has examined whether young and older adult faces are processed with regard to dissociable prototypes. Schweinberger et al. (2010) recently demonstrated that adaptation to older and young faces biases the subjective perception of the facial age of test faces; however, no study has yet investigated whether simultaneous adaptation to young and older faces distorted in opposite directions produces age-contingent opposing aftereffects. One possibility is that there is a single norm that codes for both young and older adult faces and age is represented as a dimension within face space or as a set of values along multiple dimensions (e.g., nose size, amount of wrinkles). According to this model, older adult faces are located quite distant from the prototype and are thus poorly encoded and recognized. A second possibility is that there are separable prototypes for young and older adult faces; however, the older adult prototype is poorly defined and located in the periphery of face space. Future studies should examine whether there are dissociable prototypes for young versus older adult faces and the extent to which these prototypes overlap with one another. Regardless of which model best describes our representation of older adult faces, our results indicate that older adult faces are less well represented than young adult faces.

In summary, we used normality judgments as a tool to examine the refinement of young and older adults' representation of young versus older adult faces. Despite no difference in the accuracy with which participants were able to discriminate young and older adult faces, judgments of normality were more accurate for young than older faces, which may be reflective of increased sensitivity to the dimensions along which young relative to older adult faces vary. Even older adults appear to rely on a face space that is optimized for the dimensions of young faces, which suggests that abundant experience with older faces later in life does not reverse early perceptual tuning. This deficit in the perception of older faces may contribute to an increased tendency to perceive all senior citizens as “being the same” and not having individual personalities and preferences. Given the projected growth in the senior citizen population, it is thus important to focus future research on how face perception varies as a function of participant and facial age and how seniors are perceived by younger members of society and by their peers.

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CHAPTER 6

Study 5: Attractiveness Judgments for Young and Older Faces Among 3- and 7-Year-Old Children[12]

Adults' ability to recognize faces is limited by experience. For example, they recognize own-race faces more accurately than other-race faces, presumably because they have more experience with own- than other-race faces (for a review, see Meissner & Brigham, 2001). The advantage for own-race faces emerges during infancy (Kelly et al., 2007), has been found in children as young as 3 years of age (Macchi Cassia, Luo, Pisacane, Li, & Lee, 2014b; Sangrigoli & de Schonen, 2004), and is thought to reflect a process of perceptual tuning (e.g., Kelly et al., 2005; Kelly et al., 2007; Scott, Pascalis, & Nelson, 2007) similar to that observed in music (Hannon & Trehub, 2005) and speech perception (Kuhl, Tsao, & Liu, 2003; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Maurer & Werker, 2014; Werker & Tees, 1984).

Face age also influences recognition accuracy; however, the developmental pattern is more complex, perhaps because one's own age (unlike race) continuously changes, as does the age of faces to which one is primarily exposed. Some studies report enhanced recognition for own- relative to other-age faces across all participant ages (e.g., Anastasi & Rhodes, 2005; Perfect & Harris, 2003; Rhodes & Anastasi, 2012), a pattern of results that suggests that recent life experience exerts significant influence on recognition abilities (see Wiese, Komes, & Schweinberger, 2012 for a demonstration of an own-age bias among older adults with high experience with other older adults but not among older

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[12] This chapter is based on a paper that is currently in press: Short, L. A., Mondloch, C. J., & Hackland, A. T. (in press). Attractiveness judgments and discrimination of mommies and grandmas: Perceptual tuning for young adult faces. *Journal of Experimental Child Psychology.*

adults with low experience with other older adults). In contrast, other studies report comparable recognition for young adult faces relative to own-age faces even in children and older adults (e.g., Fulton & Bartlett, 1991; Wallis, Lipp, & Vanman, 2012; Wiese, Schweinberger, & Hansen, 2008; Wolff, Wiese, & Schweinberger, 2012); this pattern of results is consistent with the view that young adult faces are the most frequently encountered (Rennels & Davis, 2008) and socially relevant (Scherf & Scott, 2012) face age category early in life, which sets up a life-long perceptual bias for young adult faces (Macchi Cassia, 2011). Consistent with this argument, Macchi Cassia, Bulf, Quadrelli, and Proietti (2014a) recently reported evidence of a perceptual processing advantage for young adult relative to infant faces in 9- but not 3-month-old infants. Here we investigate the development of a perceptual bias during childhood for young compared to older adult faces, a bias that may underlie superior recognition of young faces among young and, in many cases, older adults.

One explanation for superior recognition for faces from highly familiar categories (including own-age or young adult faces) is norm-based coding, a process by which individual faces are coded relative to a face prototype that represents the average of all faces previously encountered (Valentine, 1991). Within this multidimensional face space, individual faces are represented as distinct points; the farther a face is from the prototype, the less attractive and more distinctive it appears (Rhodes & Tremewan, 1996; Valentine, Darling, & Donnelly, 2004). Norm-based coding is thought to facilitate discrimination around the norm (Armann, Jeffery, Calder, & Rhodes, 2011; Wilson, Loffler, & Wilkinson, 2002). Because face space is optimized for differentiating individual faces within frequently encountered categories, faces from other categories are recognized less accurately (Valentine & Endo, 1992). Differences in how faces from various age categories (e.g., own age, young adult) are represented in face space may account for how well individual faces from those categories are differentiated and recognized.

Short and Mondloch (2013) recently reported that both young and older adults are more sensitive to how young adult faces, compared to older adult faces, deviate from an undistorted face. Parallel results for both age groups (i.e., the lack of a reversal in older adults) suggests that early and continuous experience with young adult faces tunes the perceptual system to the dimensions of young adult faces, with later experience having less impact. In the current study, we tested the hypothesis that children as young as 3 years of age would show a similar advantage for young adult faces compared to older adult faces, as would be expected if early experience tunes the perceptual system.

Short and Mondloch (2013) showed participants young and older adult face pairs in which one member of each pair was undistorted and the other had compressed (-10%, -20%, -30%) or expanded (+10%, +20%, +30%) features. In the normality task, participants indicated which member of each pair was more normal, and in the discrimination task, participants indicated which member of each pair was more expanded. Both age groups were more accurate when tested with young compared to older faces—but only when judging normality. The presence of a young adult face advantage in the normality but not the discrimination task was attributed to differences in the perceptual processing strategies required by the two tasks. Whereas the identification of a normal-looking face requires reliance on perceptual expertise (e.g., use of a well-defined norm), the identification of the expanded face in a pair only requires participants to be able to tell the two faces apart, which they can do using a feature-based approach (e.g., determine which face has the larger nose or has more space between the eyes). Such a processing strategy does not require expertise or the use of norm-based coding, as demonstrated by the finding that inversion reduces accuracy of normality judgments but not accuracy of discrimination (Short & Mondloch, 2013, Experiment 2). To further illustrate the differences between the two tasks, imagine participants are shown pairs of coffee mugs; in each pair, one mug is undistorted while the other mug is expanded or compressed. Participants could easily identify the expanded mug by determining which mug has the largest handle. However, identifying the more normal looking mug in each pair would be significantly more difficult, unless the participant had received ample experience in examining mugs of different shapes and sizes. In this same way, adults are fully capable of identifying expanded young and older faces but appear to lack the expertise and sensitivity required to judge the normality of older relative to young adult faces. Short and Mondloch thus attributed the deficit for older faces in the normality task to decreased reliance on a well-refined norm for older faces.

In the current study, we examined the emergence of this pattern of results in childhood by creating a child-friendly version of the normality and discrimination task. We tested 3- and 7-year-old children on both an attractiveness judgment and a match-to-sample (discrimination) task. In the attractiveness task, children viewed young and older adult face pairs; one member of each pair was undistorted and the other had features that were compressed towards the center of the face or expanded outward. Children were asked to point to the prettiest face, which served as a measure of their sensitivity to the dimensions on which faces vary relative to a norm. We elected to use attractiveness judgments rather than normality judgments because past studies examining children's use of a norm have relied on ratings (Anzures, Mondloch, & Lackner, 2009) and judgments of attractiveness (Short, Hatry, & Mondloch, 2011; Short, Lee, Fu, & Mondloch, 2014), and because adults show similar sensitivity to facial distortions whether they are asked to judge normality or attractiveness (Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003). Although many factors influence perceived attractiveness (e.g., symmetry, sexual dimorphism; see Rhodes, 2006), with some deviations from average making a face especially attractive (e.g., increased eye size; Geldart, Maurer, & Carney, 1999), our distortions were so large that they made the faces verge on grotesque. Thus, selecting the unaltered face as most attractive was deemed to be the correct response and indicative of how a face varied from the norm.

Reduced accuracy for older than young adult faces in the attractiveness task could reflect either specific deficits in referencing a norm for older faces (as shown by adults) or general deficits in discriminating older faces (i.e., telling the two faces in the pair apart from each other). To examine whether biases in the attractiveness task were due to specific deficits in norm-based coding or to general impaired discrimination, we also tested children on a simultaneous match-to-sample task with young and older faces using the same stimuli. Children were asked to match the sample face (e.g., the compressed version) to one of two test stimuli (e.g., the compressed and undistorted versions). Reduced accuracy for older than young adult faces in the discrimination task would indicate impaired discrimination of older faces even when referencing a norm was not required; similar accuracy across face ages, as observed previously in adults (Short & Mondloch, 2013), would indicate that children’s perceptual tuning for young adult faces may be specific to norm-based coding. All children were first tested on the attractiveness task followed by the match-to-sample task because our primary interest was in whether children, like young and older adults, showed differential performance in gauging the attractiveness of young and older faces, and the match-to-sample task simply served as a control.

We elected to test 3- and 7-year-olds for several reasons. First, by age 3 years children show an own-race recognition advantage (Macchi Cassia et al., 2014b; Sangrigoli & de Schonen, 2004) and there is substantial evidence that face age influences their performance in delayed match-to-sample tasks (Macchi Cassia, Kuefner, Picozzi, & Vescovo, 2009; Macchi Cassia, Pisacane, & Gava, 2012; Proietti, Pisacane, & Macchi Cassia, 2013). Furthermore, 3-year-olds are capable of assessing attractiveness (e.g., Dion, 1973) and their perceptions of facial attractiveness are influenced by experience (Cooper, Geldart, Mondloch, & Maurer, 2006). However, because current studies have found evidence for norm-based coding only in children as young as 4 years (youngest age tested; Jeffery et al., 2010; Jeffery, Read, & Rhodes, 2013b; Short et al., 2011), we also tested an older group of children (7-year-olds). By 7 years of age, norm-based coding is well in place at least for own-race faces, and there is evidence that face space becomes increasingly differentiated between 5 and 8 years of age (Short et al., 2011; Short et al., 2014). Both 3- and 7-year-olds were tested with the same protocol in the attractiveness and match-to-sample tasks; however, we used different distortion levels for the two age groups (±70% for 3-year-olds and ±50% for 7-year-olds). These values were selected based on published studies (Anzures et al., 2009; Short et al., 2011) and on pilot testing that revealed that 7-year-olds were at ceiling when tested with ±70% faces and performed poorly when judging the attractiveness of faces distorted by less than ±50%.

We hypothesized that, like adults, 3- and 7-year-old children would show an advantage for young faces in the attractiveness task. Among young and older adults, the young adult face advantage was eliminated in the discrimination task, presumably because this task did not require perceptual expertise and participants could rely on a featural approach (Short & Mondloch, 2013). If children's performance deficit for older faces in the attractiveness task is specific to norm-based coding (e.g., a poorly refined norm for older faces), then they should show comparable performance for young and older faces in the match-to-sample task. However, if their performance deficit for older faces in the attractiveness task extends beyond the use of norm-based coding to general difficulty in detecting even feature-based differences among older faces, then they should also show a young adult face advantage in the match-to-sample task. One study to date (Proietti et al., 2013) used a match-to-sample task to examine the ability to distinguish between young and older adult faces and found that both adults and 3-year-olds with minimal experience with older adult faces showed a young adult face advantage. However, this study involved a delayed two-alternative forced-choice task and assessed recognition of individual face identities; no study has yet examined whether young children continue to show a young adult face advantage in an immediate perceptual task that has no memory demands and involves the comparison of same-identity faces.

Method

Participants

Thirty Caucasian 3-year-olds (15 female; mean age = 3 years 7 months; age range = 3 years 1 month to 3 years 11 months) and 30 Caucasian 7-year-olds (19 female; mean age = 7 years 7 months; age range = 7 years 0 months to 7 years 11 months) participated in this study. An additional 10 children were tested but excluded from all analyses due to experimenter error (two 7-year-olds) or because they failed criterion (two 3-year-olds), did not understand task instructions (two 3-year-olds), or were inattentive (four 3-year-olds). Children were tested on both the attractiveness task and the match-to-sample task during the same session, and there was a 5-minute break between tasks.

Attractiveness Task

Materials. Color facial photographs of 12 Caucasian young women (age range = 20-27 years) and 12 Caucasian older women (age range = 71-79 years) were used as test stimuli. Face images were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) and from a sample of photographs taken in the Face Perception Lab at Brock University; face identities were identical to the female identities used by Short and Mondloch (2013). The 24 identities were divided into two sets of 12 (six young, six older). Each face set was shown to half of the participants. We used the spherize tool in Adobe Photoshop Version 12.0 to expand and compress the internal features of each face identity; using this technique, we created two new versions of each identity, one that was expanded and one that was compressed. To avoid floor and ceiling effects, we compressed and expanded each identity ±70% for 3-year-olds and ±50% for 7-year-olds, values selected based on pilot testing and published studies (Anzures et al., 2009; Short et al., 2011). For each identity, we then created two face pairs in which the undistorted version was paired with the expanded and compressed versions (see Figure 6.1 for sample stimuli). Each face in the pair was standardized such that the distance between the chin and hairline was approximately 300 pixels, and the gap between the two faces in each pair was approximately 600 pixels.

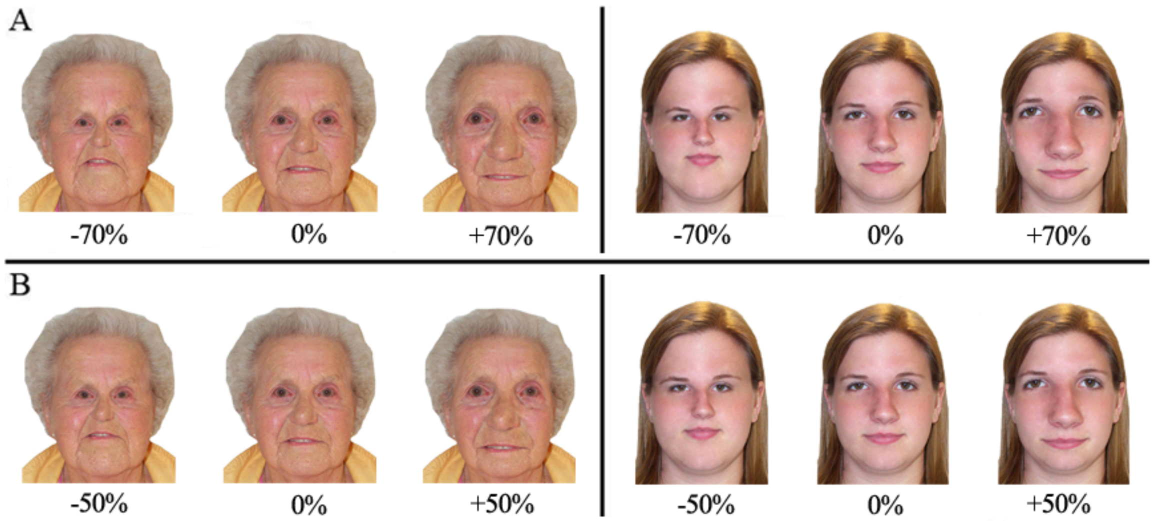

Figure 6.1. Sample distortion continua for an older adult identity and a young adult identity, as shown to 3- (Row A) and 7-year-old (Row B) participants. Each face pair consisted of an undistorted face paired with an expanded or compressed version of the same identity.

Of the 12 face pairs presented to each participant, six (three young) consisted of an undistorted face paired with its expanded version and six (three young) consisted of an undistorted face paired with its compressed version. For each identity, half of the participants saw the expanded face pair and the other half saw the compressed face pair. Each face set was presented in one of four random orders to each participant and the undistorted face was on the left for half of the trials.

Criterion stimuli were used in order to keep children engaged and to verify that children remained on task throughout the duration of the experiment. The eight pairs of criterion stimuli (based on those used by Cooper et al., 2006, Experiment 3) consisted of two hand-drawn versions of the same object, one that was brightly colored and shiny and the other that was dull and dirty (e.g., a pencil with bright colors paired with a brown, chewed-up pencil).

Procedure. Before beginning the task, children completed two trials designed to illustrate the concept of prettiness. In each trial, children were shown two versions of the same object (a pair of teddy bears and a pair of gloves); one was in store-bought condition and the other had holes and stains on it. Children were asked to indicate which object was the prettiest. Children were praised after making a correct response; regardless of the response made, the experimenter highlighted differences between the two objects that resulted in one being prettier.

Following these illustration trials, participants were seated approximately 60 cm in front of a 24-inch computer monitor. Children were told that they were going to play a game in which mommies and grandmas were going on a trip to the zoo. The task comprised eight criterion and 12 test trials; sets of criterion ($n = 2$) and test ($n = 4$) trials alternated, beginning with criterion trials. Prior to the first criterion trial, children were shown a magic backpack on the screen and the task was explained. On each criterion trial, children were shown a pair of objects and asked to wave a magic wand over the prettiest one; objects remained on the screen until a response was made, at which point the backpack appeared, a sound was played, and the child received non-contingent verbal reinforcement. Children were required to be correct on at least six criterion trials to be included in the final analysis. Prior to the first test trial, children were shown a picture of a bus and the task was explained. On each test trial, children were shown a pair of faces (two versions of the same identity) and asked to wave the wand over the prettiest mommy or grandma so that she could get on the bus; the experimenter indicated via key press whether the child waved the wand over the right or left side of the screen. Faces remained on the screen until a response was made, at which point the bus appeared with silhouettes of people inside (the number of which increased across trials) and the child received verbal reinforcement.

Match-to-Sample Task

Materials. Each participant was tested with eight (four young, four older) of the 12 identities they had judged during the attractiveness task; we used only a subset of the identities in the match-to-sample task in order to keep the task brief and sufficiently engaging for young children. On each trial, participants viewed a target face paired with two versions of the same identity; one version was undistorted and the other was either expanded or compressed (counterbalanced). Distortions were consistent with those used in the attractiveness task (±70% for 3-year-olds and ±50% for 7-year-olds). For each face age, the target face was undistorted for half of the trials ($n = 2$) and distorted (1 compressed; 1 expanded) for the other half. Using Velcro, the target face was placed on a piece of poster board above a pair of faces, one of which was identical to the target (see Mondloch & Thomson, 2008 for a similar method used with 4-year-old participants).

Based on Mondloch and Thomson (2008), criterion stimuli comprised pictures of animals. In each of four criterion trials, two animals were identical (e.g., two brown squirrels) and the third animal differed in its features or color (e.g., a squirrel with pig ears). Children were required to respond correctly on at least three criterion trials to be included in the final analysis. We also created a twin clubhouse, which we used to describe the concept of twins, and children were told to imagine that only people who looked alike were allowed to enter the clubhouse.

Procedure. As in Mondloch and Thomson (2008), children received one practice trial in which they were shown pictures of three umbrellas and were asked to point to the umbrella at the bottom of the board that looked just like the one at the top; incorrect responses were corrected for this trial only, to ensure that children understood the task. Children then completed four criterion and eight test trials. On each trial, the experimenter pointed to the target image and asked, “Which of the two pictures on the bottom looks exactly the same as the one on the top?” Children then pointed to the picture that they thought was the exact same as the target image at the top of the board, and the experimenter recorded their response on a sheet of paper. Trials were administered in the following sequence: criterion ($n = 1$), test ($n = 4$), criterion ($n = 2$), test ($n = 4$), criterion ($n = 1$).

Results

Children made almost no errors on either set of criterion trials. Only six 3-year-olds and one 7-year-old made errors on criterion trials in the attractiveness task, mean correct (on 8 trials) = 7.87, and only five 3-year-olds and one 7-year-old made a single error on criterion trials in the match-to-sample task, mean correct (on 4 trials) = 3.90.

For both the attractiveness and match-to-sample tasks, performance was assessed in terms of the mean proportion of correct faces chosen. In the attractiveness task, selection of the undistorted face as prettiest was scored as correct because it indicated a preference closer to the norm, consistent with adult (Langlois & Roggman, 1990) and child (Vingilis-Jaremko & Maurer, 2013) preferences for averageness. Data were collapsed across expanded and compressed trials, as preliminary analyses indicated that there was no main effect of distortion type, $p = .44$, and distortion type did not interact with any other variables, all *p*s > .08. Single-sample t-tests revealed that for both participant age groups, accuracy was significantly greater than chance (.50) and significantly below ceiling (1.0) for both young and older faces in each task, all *p*s < .05. A 2 (task: attractiveness, match-to-sample) x 2 (face age: young, older) x 2 (participant age: 3-year-olds, 7-year-olds) mixed ANOVA revealed a main effect of task, $F(1, 58) = 14.53$, $p < .001$, $\eta_p^2 = .20$. Children were more accurate on the match-to-sample task ($M = .87$, $SE = .02$) than the attractiveness judgment task ($M = .78$, $SE = .02$). There was also a main effect of face age, $F(1, 58) = 17.87$, $p < .001$, $\eta_p^2 = .24$; accuracy was higher for young ($M = .86$, $SE = .02$) than older adult faces ($M = .78$, $SE = .02$). Lastly, there was a main effect of participant age, $F(1, 58) = 22.86$, $p < .001$, $\eta_p^2 = .28$; 7-year-olds were more accurate overall ($M = .90$, $SE = .02$) than 3-year-olds ($M = .74$, $SE = .02$), despite

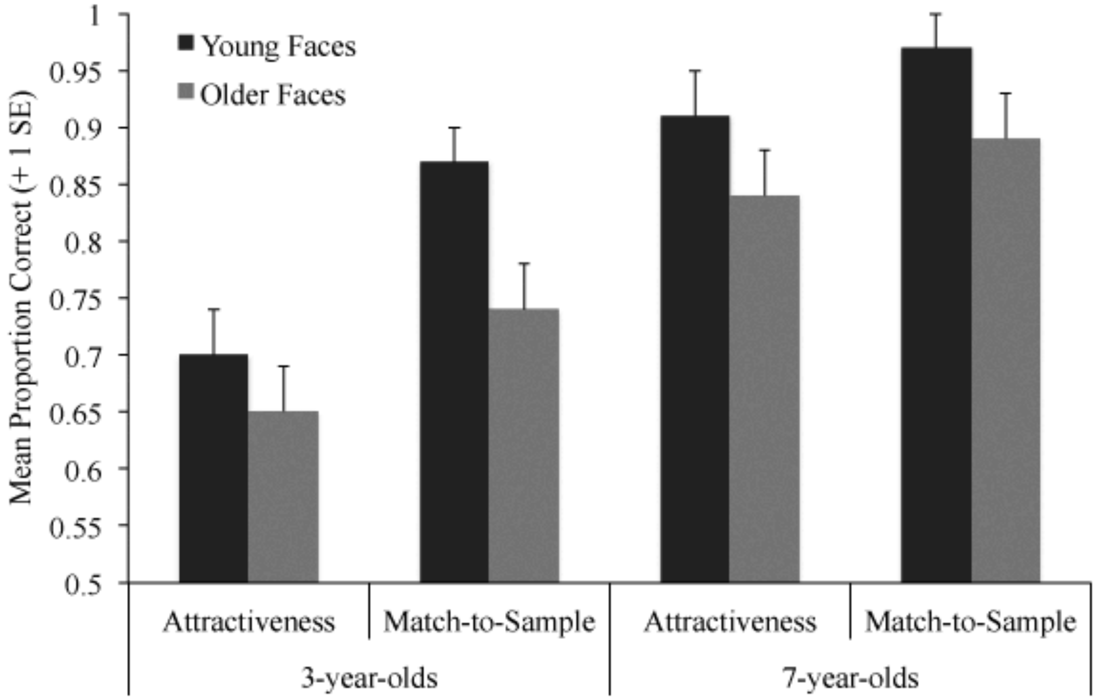

Figure 6.2. Mean proportion correct (+1 SE) for young and older adult faces in the attractiveness and match-to-sample tasks for both participant age groups.

being tested with a more difficult set of stimuli. There were no significant two- or three-way interactions, all *p*s > .12, η_p^2s < .04. Crucially, there was no task by face age interaction, $F(1, 58) = .88$, $p = .35$, $\eta_p^2 = .02$, revealing that the young adult bias was not specific to the attractiveness task (see Figure 6.2).

Finally, we examined whether there was a correlation between individual performance across the attractiveness judgment and match-to-sample tasks. There was a marginally significant positive correlation between performance with young adult faces across the two tasks, $r = .25$, $p = .06$, and a significant positive correlation between performance with older adult faces across the two tasks, $r = .37$, $p = .004$.

Discussion

Like adults (Short & Mondloch, 2013), both 3- and 7-year-old children showed greater accuracy in judging the attractiveness/normality of young relative to older adult faces. However, whereas adults were equally accurate in discriminating between young and older faces, 3- and 7-year-olds were more accurate with young faces in the simultaneous match-to-sample task. Adults' superior performance with young faces in the normality task but not the discrimination task suggests that their bias for young faces is specific to the use of norm-based coding; in particular, deficits in judging the normality of older faces may be due to reliance on a face space that is optimized for the dimensions of young adult faces. Although adults' ability to reference each face to a prototype is superior for young faces, they are equally capable of discriminating young and older faces, presumably because they are able to rely on a feature-based strategy. In contrast, 3- and 7-year-olds' young adult face bias extended to the match-to-sample task, which suggests that their superior performance with young faces in the attractiveness task may be partially attributable to reduced sensitivity to large differences in feature shape or spacing in older than in young adult faces. Consistent with this idea is our finding of a positive correlation between performance with older faces across the two task types, indicating that deficits in judging the attractiveness of older faces were associated with deficits in discrimination.

Although there were several methodological differences between our child-friendly tasks and the adult versions used by Short and Mondloch (2013), we contend that the attractiveness and match-to-sample tasks administered to children tapped comparable perceptual processes to the normality and discrimination tasks previously administered to adults. First, as noted in the introduction, both judgments of attractiveness and normality reflect sensitivity to deviations from the norm, and past studies have repeatedly used the highly familiar concept of prettiness when testing young children (e.g., Anzures et al., 2009; Cooper et al., 2006). On the surface, the tasks used to measure discrimination in adults and children differed; whereas adults were asked to indicate which of two faces in a pair was more expanded, children were tested with a match-to-sample task. However, in both discrimination tasks, faces were presented simultaneously and participants simply needed to indicate that they could tell the two faces apart (i.e., participants were not required to reference a norm). Although the differences in methodology preclude a direct comparison between children's and adults' performance, differences in the pattern of results within each age group are informative. First, given that children showed deficits for older faces in both the attractiveness and the discrimination tasks, we can conclude that the young adult face bias emerges as early as 3 years of age. Second, whereas adults' bias was specific to norm-based coding, perceptual tuning in children appears to include decreased sensitivity to even feature-based differences in older faces; indeed their ability to use norm-based coding for older adult faces may be limited by their ability to discriminate among them.

Our results cannot be attributed to either floor or ceiling effects. We avoided floor effects by adjusting distortion levels for each age group based on pilot data and a previously published study (Anzures et al., 2009). Consequently, accuracy was well above chance for both face ages in all conditions, ruling out the possibility that either task was too difficult for children to complete. The performance of 7-year-olds was near ceiling (though significantly different from 1.0) when discriminating young adult faces in the match-to-sample task; however, this does not weaken our conclusion that children's deficit for older adult faces extends to the discrimination task for several reasons. First, 3-year-olds showed neither ceiling nor floor effects, yet exhibited a pattern of results comparable to that of 7-year-olds. Second, 7-year-olds' accuracy for older faces on the match-to-sample task (89%) was comparable to young adults' accuracy for older faces on the discrimination task (92%; Short & Mondloch, 2013), but only 7-year-olds showed superior performance when discriminating young adult faces. Third, 7-year-olds were not at ceiling for the attractiveness task. In the attractiveness task, there was plenty of opportunity for accuracy on young adult face trials to increase and for accuracy on older adult face trials to decrease; however, the magnitude of the young adult face bias was no larger in the attractiveness task than in the match-to-sample task. This is especially notable given that potential ceiling effects for young adult faces may have minimized the effect of face age in the match-to-sample task, enhancing the opportunity for a larger effect of face age in the attractiveness judgment task.

Our results are consistent with past studies showing that children show reduced sensitivity to facial distortions relative to adults (Jeffery et al., 2010; Jeffery, Rathbone, Read, & Rhodes, 2013a) and provide evidence that sensitivity to the dimensions of face space improves between 3 and 7 years of age. Despite being tested with less extreme facial distortions, 7-year-olds were more accurate than 3-year-olds on both tasks. Furthermore, 7-year-olds' accuracy was comparable to that of young adults despite being tested with more extreme distortions. Our findings are consistent with evidence that children are less sensitive than adults to distortions that increase the grotesqueness (Mondloch, Dobson, Parsons, & Maurer, 2004) or distinctiveness (McKone & Boyer, 2006) of a face and require greater differences among faces in order to consistently rate unaltered faces as more attractive than faces with compressed or expanded features (Anzures et al., 2009). Improved sensitivity to the dimensions of face space may thus be one factor that contributes to increased face recognition across childhood.

Norm-based coding likely facilitates face recognition (Rhodes, Jeffery, Taylor, Hayward, & Ewing, 2014; Rhodes & Leopold, 2011; Wilson et al., 2002). Adults' face space is characterized by dissociable category-specific norms (e.g., Jaquet, Rhodes, & Hayward, 2008; Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005; Little, DeBruine, Jones, & Waitt, 2008) and is optimized for faces from frequently encountered categories (Rhodes et al., 2014; Valentine & Endo, 1992). Although children as young as 4 years appear to reference a norm (as shown by figural and identity aftereffects; Jeffery et al., 2010; Jeffery et al., 2013b; Short et al., 2011), they rely on a single category-generic prototype, with category-specific norms emerging between 5 and 8 years of age (Short et al., 2011; Short et al., 2014). Our current data suggest that differential sensitivity to even featural distortions precedes the development of age- and perhaps other category-specific norms. Although young children are less sensitive than adults to large featural differences among faces, our findings show that by 3 years of age children are more sensitive to differences among young adult faces than older adult faces, reflecting the emergence of adult-like perceptual tuning for young adult faces.

Our data also contribute to the debate about whether there is any domain-specific development in face perception throughout childhood. Weigelt et al. (2014) argue that whereas improvements in face memory during childhood are domain specific, improvements in face perception are entirely attributable to domain-general processes. Children's overall accuracy on any face perception task likely is influenced by general cognitive development (e.g., Baudouin, Gallay, Durand, & Robichon, 2010; Mondloch et al., 2004; Mondloch, Maurer, & Ahola, 2006). However, we contend that age-related improvements in our tasks cannot be attributed to domain-general cognitive development alone. Even 3-year-olds performed largely without error on criterion trials, demonstrating that limitations in attention cannot account for children's errors throughout the task. Although more 7-year-olds than 3-year-olds were errorless on criterion trials, 20 of the 30 3-year-olds tested were completely without error on both tasks, indicating that the majority of 3-year-olds encountered no difficulty in completing object trials. Moreover, improvements in accuracy were comparable across the two task types, even though the match-to-sample task had no memory demands, and were evident even for young adult faces, a category with which young children have abundant experience (Rennels & Davis, 2008). Lastly, general cognitive development alone cannot explain differential performance for young and older faces given that faces from these two categories were presented in identical tasks.

One limitation of the present study is that all children were first tested on the attractiveness task followed by the match-to-sample task, and the same identities were used in both tasks. A specific merit of Short and Mondloch (2013) is that the authors used the same identities in the normality and discrimination tasks, which allowed them to directly compare performance across the two tasks. We thus elected to use the same faces in both of our tasks; however, one possible effect is that exposure to the identities in the attractiveness task may have made the match-to-sample task less difficult. However, despite higher overall accuracy in the match-to-sample task, children continued to show differential performance for young and older adult faces in both tasks. Furthermore, Short and Mondloch counterbalanced task order in their study, yet found that it did not significantly interact with any other variables and that, like children, adults' accuracy was higher in the discrimination task regardless of the order in which the tasks were administered.

Experience with different face ages may affect the extent to which children show a young adult face bias (Proietti et al., 2013). Future studies should examine whether children raised by grandparents (i.e., with exposure to two older adult exemplars on a daily basis) or in aging communities (i.e., with exposure to numerous older adults on a regular basis) show the reverse pattern of results. Short and Mondloch (2013) demonstrated that significant exposure to older adults later in life is not sufficient to bias the dimensions of face space toward older faces; however, this same amount of exposure in childhood may alter the system to a greater extent, as there is some evidence that the face processing system is more malleable early relative to later in life (e.g., Hills, Holland, & Lewis, 2010; Macchi Cassia et al., 2009). Such studies would be most informative if they examined the stability of individual differences in task performance, which we were unable to do in the current study because participants were tested only once (precluding an examination of test-retest reliability) and were given only a small number of trials (precluding an examination of split-half reliability). Future studies should also examine the earliest age at which the young adult face bias emerges; Macchi Cassia et al. (2014a) recently reported evidence of perceptual tuning for young adult relative to infant faces by 9 months of age, yet no study to date has examined the specificity of this bias for young (relative to older) adult faces.

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CHAPTER 7

General Discussion

Since its initial conception, the Valentine (1991) model of face space has motivated numerous studies and explained a wide range of phenomena in the face processing literature (e.g., inversion effects, own-race recognition advantage, caricature effects). In recent years, the original model has undergone significant revision; in particular, the discovery of opposing face aftereffects has led to the suggestion that there are numerous face prototypes (rather than a single prototype) that represent the different face categories encountered in the environment (Jaquet & Rhodes, 2008; Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, & Jones, 2005; Little, DeBruine, Jones, & Waitt, 2008; Rhodes et al., 2004). However, few studies to date have examined the development of such separable prototypes and the way in which experience influences the refinement of the coding dimensions associated with different face categories. The current series of studies was thus designed to investigate the organization and refinement of face space and the role of experience in shaping sensitivity to its underlying dimensions.

The results of Study 1 demonstrate that face space is organized with regard to norms that reflect face categories that are both visually and socially distinct; a social categorical difference in the absence of a physical difference is not sufficient to elicit opposing aftereffects. These results suggest that aftereffects do in fact reflect sensitivity to the coding dimensions of face space that are based on physical characteristics; high-level semantic category membership alone does drive the emergence of separable face prototypes. Furthermore, combined with studies showing that physical differences alone do not elicit opposing aftereffects (Bestelmeyer et al., 2008; Jaquet, Rhodes, & Hayward, 2007), these results provide an indication of the types of category-specific prototypes that can conceivably exist in face space.

Study 2 was designed to investigate whether young children exhibit evidence for category-specific face prototypes and the extent to which experience facilitates the development of separable norms. Although numerous studies have demonstrated that children as young as 4 years of age rely on norm-based coding (Jeffery et al., 2010; Jeffery, Read, & Rhodes, 2013; Short, Hatry, & Mondloch, 2011), there is evidence that their face space is less well refined than that of adults. For example, they require greater differences between faces in order to consistently rate unaltered faces as more attractive than distorted faces (Anzures, Mondloch, & Lackner, 2009; Crookes & McKone, 2009; Jeffery et al., 2010) and exhibit difficulty in coding multiple dimensions simultaneously (Nishimura, Maurer, & Gao, 2009). In Study 2, I demonstrated that unlike adults and older children, 5-year-olds rely on a face space that is relatively undifferentiated with regard to different face categories. Although both Caucasian and Chinese 5-year-olds showed partial transfer of aftereffects across face race, they showed no evidence for race-contingent opposing aftereffects. Even for face categories with which children receive ample experience (race among children raised in a multiethnic environment, sex, and age), 5-year-olds continued to show no evidence for opposing aftereffects. These results suggest that although the basic mechanisms that underlie expertise in face processing are in place by early childhood, the dimensions of face space continue to undergo significant refinement throughout childhood. Five years of experience with a given face category is not sufficient to facilitate the development of adult-like separable face norms.

In Studies 3 through 5, I specifically examined how early and continuous exposure to young adult faces may optimize the face processing system for the dimensions of young adult faces. In Study 3, I examined the equivocal findings for an own-age recognition advantage among older adults by designing a recognition task that more closely mimicked how faces are encountered in the real world. During learning, young and older faces were presented in the context of naturalistic scenes (e.g., parks, outdoor shopping centers) and participants could selectively allocate their attention to either face age as well as to the background context. Both young and older adults looked longer at young than older faces, and in the recognition task, young adults showed an own-age bias and older adults showed comparable recognition for both face ages. However, differential allocation of attention at learning was unrelated to the magnitude of the own-age recognition advantage. These results provide evidence for a young adult bias in allocation of attention and suggest that despite the significant experience that older adults have with older faces, the early and continuous exposure they received with young faces continues to exert influence on their recognition abilities and equate performance across the two face ages.

Continued recognition for young adult faces in older adulthood may be because such recognition is supported by reliance on a face space that is optimized for the dimensions of young adult faces. In Studies 4 and 5, I examined whether sensitivity to deviations from the norm is superior for young relative to older adult faces. I used judgments of normality/attractiveness as a measure of this sensitivity; to examine whether any biases were specific to reliance on a norm, I asked participants to discriminate between the same face pairs. Both young and older adults were more accurate when tested with young relative to older faces—but only when judging normality. These results suggest that the dimensions of face space are optimized for young adult faces and that abundant experience with older faces later in life does not reverse this perceptual tuning. Like adults, 3- and 7-year-old children were more accurate when tested with young compared to older faces. However, accuracy was higher for young than older faces in both the attractiveness judgment and the discrimination task, suggesting that young children have a deficit for processing even feature-based differences in older faces, perhaps because their perceptual system has narrowed as a function of predominant exposure to young adult faces (see Macchi Cassia, Bulf, Quadrelli, & Proietti, 2014 for evidence of perceptual narrowing for young adult relative to infant faces).

Collectively, the results of this dissertation help us to better understand the development of category-specific face norms and elucidate the role of experience in shaping sensitivity to the underlying dimensions of face space. Unlike adults, young children appear to rely on a category-generic face prototype that gradually differentiates over time, likely as a function of both domain-general and face-specific development. Early experience clearly affects the face processing system; even 3-year-olds show an own-race recognition advantage (Sangrigoli & de Schonen, 2004) and the magnitude of this effect remains consistent throughout childhood so long as children remain in a racially homogenous environment (Anzures et al., 2014). However, such experience is not sufficient to facilitate the development of separable category-specific prototypes by 5 years. Such effects do appear to be emerging in early childhood; 5-year-olds show partial transfer of aftereffects across race categories (rather than complete transfer which would indicate entirely overlapping face prototypes) and even 3-year-olds show superior discrimination and accuracy in attractiveness judgments for young relative to older faces, which suggests that the perceptual system is tuned towards the dimensions of the most frequently encountered face age categories. Lastly, experience does not exert the same degree of influence in older adulthood as it does in childhood. Despite receiving significant daily life exposure to older adults, senior citizens continue to show an attentional bias for young faces, greater accuracy in gauging the normality of young faces, and comparable recognition performance for young and older faces.

Race versus Age

Throughout the current series of studies, I examined the organization and refinement of face space with regard to two salient face categories: race and age. Although these two categories are often considered analogous to one another (e.g., Wiese, Komes, & Schweinberger, 2012), there is one key difference: Whereas race is a stable characteristic, age constantly changes throughout the lifespan. Such changes reflect not only deviations in physical appearance but also the extent to which individuals encounter and identify with different age-related social groups. For example, an adult consistently belongs to the same race-based in-group but belongs to several different age-based in-groups throughout the lifespan (e.g., during adolescence, young adulthood, and older adulthood). Furthermore, older adult faces are particularly unique as a face category because these faces were likely distributed around and close to the young adult norm earlier in development but gradually acquired novel dimensions and moved away from that norm as a function of the physical and structural changes that accompany aging. This is in contrast to other-race faces, which consistently belong to the same out-group category and do not gradually acquire the dimensions of own-race faces.

By examining the effects of face race and age separately but through the use of the same experimental paradigms (e.g., adaptation and aftereffects, normality judgments), it is possible to further examine the role of experience in shaping the face processing system and the extent to which face race and face age shape the perceptual system in the same way. There is ample evidence to suggest that the advantage for own-race faces emerges during infancy (Kelly et al., 2007), is well established by 3 years of age (Sangrigoli & de Schonen, 2004), and reflects a process of perceptual narrowing based on predominant exposure to own-race faces (Kelly et al., 2005). According to perceptual expertise accounts, differential exposure to own- and other-race faces leads to reduced holistic processing (e.g., Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004; but see Mondloch et al., 2010) and decreased sensitivity to featural and spacing differences in other-race faces (e.g., Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010; Rhodes, Hayward, & Winkler, 2006). Because of evidence that young adult faces are the most frequently encountered face age category throughout the lifespan (Rennels & Davis, 2008), perceptual expertise accounts would predict that these same effects should be observed for young adult faces. However, if other factors outside of experience exert greater influence (e.g., social cognitive factors), then race- and age-based effects may not comparable to one another. For example, regardless of the degree of experience one has with young adult faces, a child may better remember child faces than young adult faces because they view other children as members of their social in-group.

Because current research has not fully disentangled the effects of race and age, it is not possible to conclude that each of the face race-related effects reported in the present dissertation extend to face age, and vice versa. For example, young and older adults' young adult face bias in the normality judgment task (Study 4) was attributed to reliance on a face space optimized for the face category encountered most frequently throughout life (i.e., young adult faces); however, one cannot infer that this same pattern of results exists for face race without systematically testing adults with the same paradigm using own- and other-race faces. If adults show this same pattern of results for own- relative to other-race faces, this would support the conclusion that experience tunes face space toward the dimensions of the most frequently encountered face categories. However, if adults are equally accurate in gauging the normality of own- and other-race faces, this would suggest that perhaps the physical characteristics that accompany aging systematically alter faces in a way that makes perceivers less sensitive to experimental manipulations (i.e., deviations from the norm).

As a second example of the way in which face race and age may not always be considered analogous to one another, I draw attention to recent discrepant findings regarding the effects of in-group attentional biases based on race and age. Socio-cognitive accounts of cross-category recognition effects argue that in- and out-group biases lead to different processing strategies during the encoding of faces from two categories, such as race and age. Faces classified as belonging to one's in-group are processed at the highly specific individual level whereas faces classified as out-group members are processed at the more superficial categorical level (Sporer, 2001). Semplonius and Mondloch (in preparation) recently used the scene memory task employed in Study 3 to examine young adults' attentional allocation and recognition for own- and other-race faces. Participants allocated more attention to own-race faces and showed a robust own-race recognition advantage, which supports socio-cognitive models of the other-race effect. However, the results of Study 3 demonstrate that this may not be the case for face age (at least for older adult participants); although young adults did not belong to their social in-group, older adults looked longer at young than older faces.

A potential explanation for older adults' failure to show an in-group bias in attentional allocation and recognition in Study 3 relates to the population demographics of Canada and the perceived status of senior citizens in society. There is evidence that adults show increased recognition for other-race faces if the other-race face is a member of a majority group (Wright, Boyd, & Tredoux, 2003) and that own-race attentional biases are weaker among individuals who belong to a racial minority group (e.g., Indians living in the United Kingdom; Hirose & Hancock, 2007). Presumably, such effects are mitigated among minority groups because minority group members receive ample exposure to other-race faces; furthermore, social attitudes toward minority groups may also weaken any in-group biases. For example, children who belong to a perceived low-status racial minority group show little to no evidence for implicit in-group favoritism (Newheiser & Olson, 2012). It may be the case that because senior citizens are less well represented in mainstream society and are often perceived more negatively than young adults (He, Ebner, & Johnston, 2011), they can be considered comparable to a "low-status" racial minority group. Thus, older adults may be less apt to show in-group favoritism and biases in attentional allocation, which may account for the lack of an own-age bias in looking time in Study 3. One could examine whether older adults' reduced attention to older relative to young adult faces in the scene memory task is due to social factors such as perceived social status by testing older adults in a culture in which senior citizens are more highly valued and respected (i.e., East Asian societies). Older adults living in such a culture may be more apt to show an in-group bias in attentional allocation because they feel pride in their group membership and have positive social attitudes toward other older adults.

Each of the studies reported in the present dissertation examined either face race or face age separately; in no study were the two categories considered simultaneously. However, it is fully possible for a face to belong to multiple categories at the same time. For example, a face might be that of both an other-race and an other-age individual (e.g., a Caucasian young adult participant looking at a Chinese older adult face). A key issue thus concerns how faces from such double out-groups are processed. For example, is there an additive effect such that the more out-groups a face belongs to, the worse one's memory is for the face? Wiese (2012) examined this question and found no evidence for a cumulative deficit in recognizing faces that belong to more than one out-group. However, Wiese relied on an old/new recognition memory task, and no study to date has examined whether a similar pattern of results emerges in tasks employing other dependent variables, such as normality judgments and discrimination accuracy. For example, the results of Study 4 indicate that judgments of normality are less accurate for older than young adult faces. It may be the case that normality judgments are further impaired when the older faces are also those of another race (e.g., Chinese). Additional studies could also examine the extent to which aftereffects transfer across face categories that have varying degrees of similarity to the face category presented during adaptation (e.g., adapted to young Caucasian faces; tested with young Caucasian faces, young Chinese faces, older Caucasian faces, and older Chinese faces). The magnitude of transfer across categories may provide some indication of the degree of overlap between category-specific norms in face space.

Deficit for Older Adult Faces

A consistent processing disadvantage for older adult faces emerged throughout the results of Studies 3 through 5. For example, even senior citizens (who receive consistent daily exposure to older faces) were less accurate in judging the normality of older relative to young adult faces. Normality judgments are closely related to attractiveness judgments; faces that are located close to a prototype are rated as more normal looking (i.e., less distinctive) and more attractive than those that are distant (Potter & Corneille, 2008; Rhodes & Tremewan, 1996; Valentine, Darling, & Donnelly, 2004). Given young and older adults' deficit in detecting deviations from normality in older faces, I hypothesized that they also show less agreement in their attractiveness ratings of older than young adult faces. In a recent study in our lab, young and older adults were shown a series of undistorted young and older faces and were asked to rate the attractiveness of each face. Both participant age groups exhibited less consensus in attractiveness ratings for older than young faces, supporting the hypothesis that adults have a less well refined norm for older faces and that significant experience with older faces later in life is not sufficient to bias the dimensions of face space toward older faces and reverse this effect.

It may be the case that older faces are processed in a significantly different manner than young adult faces. Opposing aftereffects studies have demonstrated that adults code infant and adult faces with regard to separable face norms (Little et al., 2008); however, no study to date has investigated whether simultaneous adaptation to young and older faces distorted in opposite directions produces age-contingent opposing aftereffects. The results of Study 4 suggest that among adults, there is a clearly defined young adult norm. However, it is currently unclear whether adults rely on a separable older adult norm that is poorly defined, possess a generic norm in which age is represented as a dimension or set of values along multiple dimensions, or simply lack an older adult norm and attempt to inappropriately apply the dimensions of young adult faces to older faces.

Given that adults rely on separable prototypes for infant versus adult faces (Little et al., 2008), one possibility is that separable young adult versus older adult face prototypes exist in face space as well. Differences in physical appearance are necessary for the emergence of opposing aftereffects, which indicate the use of separable face prototypes (see Study 1). As faces age, they change in both texture and structure (Burt & Perrett, 1995). Repetitive muscular contractions over the course of the lifespan lead to the formation of wrinkles, and aging skin is further characterized by epidermal thinning and chronic inflammation of the dermis, which is associated with reductions in collagen (Farkas, Pessa, Hubbard, & Rohrich, 2013). Additional texture-based changes include increases in pigmented irregularities (Fink, Grammer, & Matts, 2006) and decreases in facial contrast between the eyes, lips, and skin (Porcheron, Mauger, & Russell, 2013), which tends to make faces appear less sexually dimorphic and take on a more masculine appearance (Etcoff, 1999). Aging also leads to changes in the skeletal structure of the face (e.g., shrinking of the jawbone; Farkas et al., 2013), a redistribution of adipose tissue, and a lengthening of cartilage in the ears and nose (Burt & Perrett, 1995).

Older adult faces therefore clearly differ from young adult faces on a number of dimensions and may be coded with regard to an age-specific norm. The lack of exposure to older adult faces throughout much of the lifespan likely leads to decreased sensitivity to the dimensions on which older faces vary and to a norm that is less well refined than that of the young adult norm. Reliance on a poorly defined norm for older faces may thus contribute to adults' decreased sensitivity to deviations from normality in older than in young adult faces.

Alternatively, it may be the case that rather than possessing separable age-specific prototypes for young and older faces, individuals instead rely on a single age-generic "adult" prototype and age is simply represented as a dimension or set of values along multiple dimensions within face space. There is evidence that caricaturing three-dimensional faces produces an increase in perceived face age (O'Toole, Vetter, Volz, & Salter, 1997), which suggests that older faces are considered more distinctive than young faces and thus should be located in the periphery of face space. According to Valentine's (1991) model, distinctive faces are more memorable than average faces; however, the results of Study 3 suggest that this is clearly not the case for older faces. This paradox in the literature has yet to be resolved, but the solution may rest in studies that systematically examine age-contingent opposing aftereffects and the magnitude of transfer of aftereffects across young and older faces.

Moreover, whereas numerous studies have examined differential processing for own- versus other-race faces, the effect of facial aging on the processing of adult faces has largely been neglected in the face perception literature. For example, only one study to date (Wiese, Kachel, & Schweinberger, 2013) has examined holistic processing for young and older adult faces (reporting evidence that both young and older adults show a larger misalignment effect for young adult faces, i.e., greater holistic processing for young faces), and no study to date has examined whether adults are less sensitive to featural or relational (i.e., feature spacing) differences in older than in young faces. If the physical characteristics of aging affect perceptual expertise, then adults should show reduced configural processing for older adult faces. However, even if such a pattern of results were found, it is difficult to isolate the factors associated with facial aging that lead to a reduction in expertise. For example, does the addition of wrinkles affect expertise or does the change in facial structure—or perhaps it may be some combination of the two? Furthermore, social cognitive factors may also bias both young and older adults' perception of older faces. Both young and older adults have more positive explicit and implicit attributions for young than older adults (He et al., 2011) and the results of Study 3 demonstrate that young and older adults exhibit an attentional bias toward young faces. Thus any deficits in processing older faces may be partially due to social cognitive factors (e.g., stereotypes, lack of attention) that lead to reduced encoding of the individuating features of older adult faces.

Development of Face Perception

A large body of research has focused on two key issues in the field of face perception: 1) whether improvements in face processing reflect domain-general versus domain-specific development (McKone, Crookes, Jeffery, & Dilks, 2012; Weigelt et al., 2014); and 2) whether phenomena such as the other-race effect are better explained by perceptual expertise or social cognitive models (e.g., Bernstein, Young, & Hugenberg, 2007; MacLin & Malpass, 2001; Meissner & Brigham, 2001; Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008). It is likely that both general cognitive and face-specific development occurs throughout childhood and that both perceptual expertise and social factors contribute to processing advantages for familiar face categories. Thus, rather than focusing on such strict dichotomies, researchers should instead examine which aspects of face perception are refined throughout childhood and the extent to which experience shapes sensitivity to the dimensions of face space. Questions of particular importance include: How malleable is face space throughout childhood? Is there a sensitive period for establishing differential sensitivity to deviations from the norm among faces of different categories? What constitutes "meaningful" experience—is mere exposure sufficient to exert influence, or does the quality (versus quantity) of experience matter more?

The results of my dissertation provide an important addition to the literature regarding the development of face perception. First, I have consistently demonstrated that the dimensions of face space undergo significant refinement throughout childhood. In both Study 2 and Study 5, children were asked to judge the attractiveness of a series of distorted faces. For all face categories (i.e., Chinese/Caucasian, male/female, adult/child, young adult/older adult), children required greater distortions than adults in order to detect that the faces deviated from normality. Sensitivity to such deviations improved with age; for example, 3-year-olds required ±70% distortions in order to consistently judge facial attractiveness whereas 7-year-olds required only ±50% distortions. Increased sensitivity to the dimensions of face space likely reflects at least some face-specific development and cannot be attributed to general cognitive development alone, as children continue to require stronger distortions than adults even when the task has no memory component and the faces are displayed simultaneously for an unlimited amount of time. Moreover, reduced understanding of task demands cannot account for deficits in children's performance in detecting deviations from normality and in discriminating faces because even 3-year-olds displayed near-perfect performance on criterion object trials (Study 5); thus the reported effects must have a face-specific developmental component.

Second, the results of my dissertation provide evidence for an additional factor that accounts for limitations in children's face processing: reliance on a face space that is poorly differentiated with regard to category-specific prototypes. Adult expertise in face perception has primarily been attributed to two underlying mechanisms: holistic face processing (e.g., Carey & Diamond, 1994; Tanaka & Farah, 1993; Tanaka & Gordon, 2011; Young, Hellawell, & Hay, 1987) and norm-based coding of identity (e.g., Rhodes & Jeffery, 2006; Rhodes & Leopold, 2011; Rhodes, Watson, Jeffery, & Clifford, 2010; Webster & MacLeod, 2011). Recent studies suggest that children as young as 4 years of age show evidence for both holistic processing (e.g., de Heering, Houthuys, & Rossion, 2007) and norm-based coding (e.g., Jeffery et al., 2010; Jeffery et al., 2013; Short et al., 2011). Despite the presence of these two hallmarks of expert face processing early in life, children continue to make more errors than adults on a variety of face perception tasks (e.g., Baudouin, Gallay, Durand, & Robichon, 2010; de Heering, Rossion, & Maurer, 2012; Freire & Lee, 2001; Mondloch, Dobson, Parsons, & Maurer, 2004; Schwarzer, 2000), indicating that their difficulties must be accounted for by some additional factor(s). One such factor is reliance on a poorly defined face space. Face identification is better around a race-specific than a race-generic average (Armann, Jeffery, Calder, & Rhodes, 2011); thus young children's use of a category-generic prototype likely impairs their recognition for faces from all categories. Such category-specific norms appear to be in place by 8 years of age; however, even at 8 years, children continue to require greater distortions than adults to show evidence of these separable norms (Short et al., 2011).

Lastly, my dissertation highlights the important role of experience in shaping sensitivity to the various dimensions of face space. Infants and children receive predominant exposure to young adult faces (Rennels & Davis, 2008). By 3 years of age, such exposure is sufficient to bias children's discrimination abilities for young relative to older adult faces, which may be the first step in optimizing face space for the dimensions of young adult faces. Likewise, past studies have shown that children as young as 3 years show a consistent own-race recognition advantage (Sangrigoli & de Schonen, 2004), presumably because they have received ample exposure to own-race faces and minimal exposure to other-race faces. The effects of differential exposure to faces from different categories appear to emerge as early as infancy. Kelly et al. (2007) demonstrated that discrimination is enhanced for own- relative to other-race faces by 9 months of age, which leads to the prediction that superior discrimination for young relative to older adult faces may also emerge as early as 9 months.

However, there are several limits to the effect of experience. First, even five years of experience with a given face category (race, sex, age) is not sufficient to facilitate the development of category-specific prototypes. Such separable norms emerge later in childhood, perhaps due to a combination of both face-specific and domain-general cognitive development. Second, experience appears to exert greater influence early, rather than later, in life. Despite receiving ample experience with older adult faces, older adults continue to show enhanced sensitivity to deviations from normality in young relative to older adult faces. Ample experience with older faces does appear to equate recognition performance for young and older adult faces shown in naturalistic scenes; however, the lack of an own-age recognition bias among senior citizens suggests that the early and cumulative experience they have received with young adult faces continues to exert significant influence on their recognition abilities. It is important to note that the current series of studies cannot disentangle the effects of early versus cumulative life experience with young adult faces (i.e., whether early or cumulative experience carries greater weight in influencing recognition for young adult faces later in life). Future studies could examine this question by comparing recognition for young adult faces among older adults who received early exposure to young adult faces to recognition for young adult faces among older adults who received little exposure to young adults early in life (e.g., were raised by grandparents).

Connections to Theory and Future Directions

Although the current research found evidence for differential sensitivity to deviations from normality for young and older faces and found that young children rely less on category-specific norms than adults (which may underlie some of their deficits in face recognition), I did not directly measure the relationship between norm-based coding and recognition performance in any of the reported studies. Future studies stemming from this work should examine the extent to which individual differences in the magnitude of the reported effects correlate with individual differences in the strength of category-contingent opposing aftereffects and the magnitude of the young adult face advantage in normality/attractiveness judgments. Reliance on separable norms (e.g., own- versus other-race norms) may be particularly beneficial in increasing the efficiency with which we process faces from different categories. Face identification is better around a race-specific relative to a mixed-race average (Armann et al., 2011), perhaps because faces naturally lie closer to a category-specific relative to a category-generic prototype. Moreover, the use of dissociable norms may ensure that only relevant dimensions are utilized to encode faces from a given category. For example, dimensions specific to Caucasian faces will not aid in encoding Chinese faces and a failure to exclude these irrelevant dimensions may increase errors in recognizing Chinese faces.

Adaptive norm-based coding of identity is thought to facilitate discrimination around the norm (Wilson, Loffler, & Wilkinson, 2002) and enhance recognition (Armann et al., 2011); however, such benefits have not been found in all studies (Nishimura, Doyle, Humphreys, & Behrmann, 2010). Rhodes, Jeffery, Taylor, Hayward, and Ewing (2014) recently found the first evidence that the magnitude of identity aftereffects for own-race faces is positively associated with own-race face expertise. These results suggest that predominant exposure to own-race faces calibrates face space toward the coding dimensions of own-race faces. However, this effect must be interpreted with caution because the correlation was only marginally significant (p = .076) and only Caucasian participants were tested. Despite the marginal effect, such results highlight the potentially adaptive role of norm-based coding and provide further support for the suggestion that face space is selectively tuned for the dimensions of the face categories most frequently encountered throughout life.

The finding that face space is optimized for the face categories to which we are most frequently exposed (i.e., own-race faces, young adult faces) is consistent with theories proposing that face recognition is partially an experience-dependent process in which selective exposure to particular types of faces specializes the system for a given category (e.g., Kelly et al., 2005; 2007). This finding is also consistent with evolutionary theories positing that organisms' neural circuits evolved via natural selection to detect and solve problems specific to their evolutionary history and environmental circumstances (Cosmides & Tooby, 1997; reviewed in Zebrowitz & Montepare, 2006). Early hominid societies were separated by great geographical distance and thus it is highly unlikely that individuals of different races would have encountered one another (Cosmides, Tooby, & Kurzban, 2003; Kurzban, Tooby, & Cosmides, 2001). Given such infrequent contact, it would not have been necessary for humans to have evolved a perceptual system sensitive to subtle deviations in other-race faces. Similarly, it is only in recent years that adults have consistently lived into old age; in our evolutionary past, individuals would have predominantly encountered young adult faces. Thus it would have been far more adaptive to have evolved a face processing system capable of detecting deviations from normality in young rather than older adult faces. Likewise, attention may be biased toward young faces simply because these faces were more apt to be encountered and viewed as more socially relevant than older faces (i.e., for mating purposes or because they posed a physical threat) in our evolutionary history.

Conclusions

In summary, the results of this dissertation provide evidence that face space is organized with regard to visually distinct and socially meaningful face categories, develops gradually throughout childhood, and is optimized for the face categories to which we are most frequently exposed. Such results have important implications for the way in which older adults and other-race individuals are perceived, remembered, and ultimately treated by other members of society and by their peers. For example, a failure to accurately perceive the dimensions of older adult faces may lead to errors in subsequent recognition, both in everyday settings and in situations that carry greater weight such as eyewitness testimonies. Moreover, deficits in the perception of older adults and other-race individuals may contribute to an increased tendency to perceive all out-group members as “being the same” and lacking individual personalities and preferences. As our society ages and becomes increasingly multicultural, it is imperative to focus future research on how face perception varies as a function of face race and age and the way in which we can reduce such deficits in perception and recognition.

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Appendix 1

Brock University
Research Ethics Office
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 11/28/2013

PRINCIPAL INVESTIGATOR: MONDLOCH, Cathy - Psychology

FILE: 04-035 - MONDLOCH

TYPE: Faculty Research STUDENT:
SUPERVISOR:

TITLE: The Development of Visual Processing

ETHICS CLEARANCE GRANTED

Type of Clearance: RENEWAL Expiry Date: 11/28/2014

The Brock University Social Sciences Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **11/28/2013 to 11/28/2014**.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before **11/28/2014**. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

____
Jan Frijters, Chair
Social Sciences Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

Appendix 2

LSCM-I Personality Inventory

Please use this list of common human traits to describe yourself as accurately as possible. Describe yourself as you see yourself at the present time, not as you wish to be in the future. Describe yourself as you are generally or typically, as compared with other persons you know of the same sex and of roughly the same age.

Before each trait, please write a number indicating how accurately that trait describes you, using the following rating scale.

1 = Extremely inaccurate
2 = Very inaccurate
3 = Quite inaccurate
4 = Slightly inaccurate
5 = Neither inaccurate nor accurate
6 = Slightly accurate
7 = Quite accurate
8 = Very accurate
9 = Extremely accurate

____Active
____Agreeable
____Anxious
____Artistic
____Assertive
____Bashful
____Bold
____Bright
____Careful
____Careless
____Cold
____Complex
____Conscientious
____Considerate
____Cooperative
____Creative
____Daring
____Deep
____Demanding
____Disorganized
____Distrustful
____Efficient
____Emotional
____Energetic
____Envious
____Extraverted
____Fearful
____Fretful
____Haphazard
____Harsh
____Helpful
____High-strung
____Imaginative
____Imperceptive
____Imperturbable
____Impractical
____Inconsistent
____Inefficient
____Inhibited
____Innovative
____Insecure
____Intellectual
____Introspective
____Introverted
____Irritable
____Jealous
____Kind
____Moody
____Neat
____Negligent
____Nervous
____Organized
____Philosophical
____Pleasant
____Practical
____Prompt

1 = Extremely inaccurate	6 = Slightly accurate
2 = Very inaccurate	7 = Quite accurate
3 = Quite inaccurate	8 = Very accurate
4 = Slightly inaccurate	9 = Extremely accurate
5 = Neither inaccurate nor accurate	

____Quiet	____Uncharitable
____Relaxed	____Uncooperative
____Reserved	____Uncreative
____Rude	____Undemanding
____Self-pitying	____Undependable
____Selfish	____Unemotional
____Shallow	____Unenvious
____Shy	____Unexcitable
____Simple	____Unimaginative
____Sloppy	____Uninquisitive
____Steady	____Unintellectual
____Sympathetic	____Unkind
____Systematic	____Unreflective
____Talkative	____Unrestrained
____Temperamental	____Unsophisticated
____Thorough	____Unsympathetic
____Timid	____Untalkative
____Touchy	____Verbal
____Trustful	____Warm
____Unadventurous	____Withdrawn

Appendix 3

BACKGROUND QUESTIONNAIRE

How old is your child? …………………………..
What is your child's ethnicity?

- **Caucasian** ☐
- **Chinese** ☐
- **Eurasian** ☐
- **Other** ___________ *(please describe)*

In which country was your child born? ..……………
How long has your child been in the country he/she is living in now? ………….......
Please list all the countries your child has lived in, the length of time in each, and the age while living there:

<u>Location</u>	<u>Duration (approx.)</u>	<u>Age when there (approx.)</u>
……………….………	…………..…..……	…………..…..……
……………….………	…………..…..……	…………..…..……
……………….………	…………..…..……	…………..…..……
……………….………	…………..…..……	…………..…..……

In which country was your child's mother born? …………….………….
What is her ethnicity? …………….………….
In which country was your child's father born? …………….………….
What is his ethnicity? …………….………….

Does your child have any other relatives who are members of other ethnic or racial groups (by birth or by marriage)? **Y \ N**
If so, please list:

Their Ethnicity	Relationship to child (aunt, cousin etc.)	By Birth/ Marriage	How often your child sees them: *Weekly*	*Monthly*	*Yearly*	*Less than Yearly*

Has your child ever lived with people from other ethnic groups? **Y \ N**
If so, please list:

<u>Their Ethnicity</u>	<u>Length of cohabitation</u>	<u>Child's age when living with them (approximately)</u>
…………..	…..……………………..	……….……………..……………..
…………..	…..……………………..	……….……………..……………..

In the following section, we would like you to indicate how well the following statements represent the type of interactions your child has with Chinese and Caucasian people. Please indicate the extent to which each statement represents **your child's** interactions by circling the number which best represents your opinion.

Scoring key:

Very strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very strongly Agree
1	**2**	**3**	**4**	**5**	**6**

1. He/she knows lots of Chinese people………..………*1 2 3 4 5 6*
2. He/she interacts with Caucasian people during recreational periods……...……………………..............………*1 2 3 4 5 6*
3. He/she lives or has lived in an area where he/she interacts with Caucasian people……………………………………….......……*1 2 3 4 5 6*
4. He/she lives or has lived in an area where he/she interacts with Chinese people……………………………………….........……*1 2 3 4 5 6*
5. He/she interacts with Chinese people during recreational periods………..........................…....………………...*1 2 3 4 5 6*
6. He/she interacts with Caucasian people on a daily basis………...................................………………….*1 2 3 4 5 6*
7.He/she socializes a lot with Caucasian people............. *1 2 3 4 5 6*
8. He/she goes to a school or day care where he/she interacts with Chinese peers……………………...……………….....………..*1 2 3 4 5 6*
9. He/she socializes a lot with Chinese people ......……..*1 2 3 4 5 6*
10. He/she knows lots of Caucasian people…....………*1 2 3 4 5 6*
11. He/she interacts with Chinese people on a daily basis………..……......................................………*1 2 3 4 5 6*
12. He/she goes to a school or day care where he/she interacts with Caucasian peers….………..……………...……………..*1 2 3 4 5 6*

Think of up to 10 friends with whom your child spends the most time. Of these 10 children:
How many are Caucasian? _______
How many are Chinese? _______
How many are any other race outside of Caucasian and Chinese? _______

Indicate your response by marking the point on the scale that applies to your child.

If your child has lived in Canada his or her entire life, answer only the second and fourth questions.

Please rate your child's amount of interaction with Caucasian individuals <u>before arriving</u> in this country

1	2	3	4	5	6	7
Little or none						*A lot*

Please rate your child's amount of interaction with Caucasian individuals <u>while living in Canada.</u>

1	2	3	4	5	6	7
Little or none						*A lot*

Please rate your child's amount of interaction with Chinese individuals <u>before arriving</u> in this country

1	2	3	4	5	6	7
Little or none						*A lot*

Please rate your child's amount of interaction with Chinese individuals <u>while living in Canada</u>

1	2	3	4	5	6	7
Little or none						*A lot*

Appendix 4

AGE QUESTIONNAIRE

Thank you for participating in our research. We recognize that individuals may differ in their ability to recognize faces. Some of these differences may be attributable to how much we experience different kinds of faces on a daily basis. Please take a few moments to complete the following questionnaire.

Your responses will be confidential.

PERSONAL INFORMATION

1. Date of birth: ______________________

2. Mark your ethnic group:

    - ❑ Caucasian
    - ❑ Asian
    - ❑ Aboriginal
    - ❑ African Canadian
    - ❑ Other (Please specify) ___________________________

3. How many people live in your household (including yourself): _______

4. Please indicate how many of those people are in each of the following age groups:

    a) Child (< 10) ____________
    b) Adolescent (11 – 17) ________
    c) Young adult (18 – 35) _________
    d) Middle adult (35 – 55) __________
    e) Older adult (56+) __________

5. Think about family members with whom you have regular contact (at least once per month). How many of those people are in each of the following age groups:

    a) Child (< 10) ____________
    b) Adolescent (11 – 17) ________
    c) Young adult (18 – 35) _________
    d) Middle adult (35 – 55) __________
    e) Older adult (56+) __________

6. Think about people with whom you spend time at work or in social situations. Rank order the following age ranges in terms of contact hours per month:

a) Child (< 10) _____________
b) Adolescent (11 – 17) _________
c) Young adult (18 – 35) __________
d) Middle adult (35 – 55) ___________
e) Older adult (56+) ___________

7. Please estimate how many hours you usually spend per week interacting with people in each of the following age groups:

a) Child (< 10) _____________
b) Adolescent (11 – 17) _________
c) Young adult (18 – 35) __________
d) Middle adult (35 – 55) ___________
e) Older adult (56+) ___________

8. In your opinion, in the last 5 years, how much experience have you had with people between the ages of

60 and 90 years?

1	2	3	4	5
minimal	some	moderate	a lot	extensive

18 to 30 years?

1	2	3	4	5
minimal	some	moderate	a lot	extensive

5 to 10 years?

1	2	3	4	5
minimal	some	moderate	a lot	extensive

9. Please provide any additional information that would indicate extensive experience with one of the above age groups.